Solar Energy
And Sustainable Development
Refereed, biannual scientific journal issued by
Center for Solar Energy Research and Studies

Energy Saving Potential of Dynamic Lighting Control in Street Lighting Systems in Libya

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Abstract: This paper studies the manner of energy consumption in Libyan street lighting systems and general road section. It also suggests proposal system with two cases of operation for an attempt to apply the energy saving program by adopting an optimum method in order to decrease the demand of energy in this section and to reduce the use of uneconomic equipment.

The proposal system in this paper introduces the Light Emitting Diode (LED) street lighting technology to be used instead of traditional luminaries High Pressure Sodium (HPS). The proposed system is divided into two cases. The first case discusses the replacement of traditional luminaries (HPS) with energy saving luminaries (LED), while second case explains how integrating control node (dynamic dimmer) into LED in order to dim output lighting in streets will save more energy.

This study reaches a result that a significant amount of energy of %47 (about 1092.23 GWh/year) of total energy consumed in street lighting sector could be saved if first case is applied. Moreover, it suggests that more energy of %58 (about 1380.02 GWh/year) of total energy consumed in the same sector cloud be saved if the second case is adopted.

إمكانية توفير الطاقة بنظام التحكم الديناميكي لإنارة الشوارع في ليبيا

صلاح محمد العبانى

مركز بحوث ودراسات الطاقة الشمسية- طرابلس- ليبيا

ملخص: تتناول هذه الورقة دراسة نمط استهلاك الطاقة في قطاع إنارة الشوارع والطرقات العامة في ليبيا. وتتضمن أيضا نظام مقترح يتكون من حالتي دراسة تشغيلية لمحاولة تطبيق برنامج توفير الطاقة، وذلك لتبني أفضل الطرق لتخفيض استهلاك الطاقة في هذا القطاع، وكذلك تقليل الاعتماد علي المعدات المستهلكة للطاقة. النظام المقترح في هذه الورقة يعرف بتكنولوجيا نظام إنارة الطرقات العامة (LED)، لاستخدامه بديلا عن نظام الإنارة التقليدي (HPS). حيث تناقش الحالة الدراسية الأولى نتائج عملية استبدال الإنارة

Solar Energy and Sustainable Development, Volume (7) № (1) Jun. 2018

التقليدية(HPS) بتقنية إنارة (LED)، بينما تشرح الحالة الدراسية الثانية عملية إدماج تقنية المتحكم في شدة الإنارة الديناميكي (dynamic dimmer) في نظام إنارة (LED) من اجل تخفيض شدة الإنارة للحصول علي أكثر وفرات في الطاقة. هذه الدراسة توصلت إلي نتائج مهمة حيث أظهرت انه يمكن تقليل استهلاك الطاقة بمقدار (1092.23 GWh/year) أي ما يعادل 47 % من الاستهلاك الكلي للطاقة في قطاع الإنارة العامة وذلك بتطبيق الحالة الدراسية الأولى، و يمكن زيادة هذه الوافرات حتى تصل إلي (1380.02 GWh/year) أي ما يعادل 58 % من الاستهلاك الكلي للطاقة في القطاع المذكور وذلك بتطبيق الحالة الدراسية الثانية..

Keywords: *street lighting; LED luminaries; dynamic dimmer; energy; street lighting.*

1. INTRODUCTION

Recently, renewable energy sources have seen a huge global interest, especially in the field of solar and wind energy.

Street lightning system is of important necessity for having safe city traffic and for increasing the level of comfort for citizens. Therefore, in most cases the lighting systems tend to be as wide as the city layout itself, and consequently allot of luminaries that consume a significant amount of electrical energy are used. At the beginning, street lamps were manually controlled as the control switch unit had to be set in street lamps in each street. But, nowadays, new technology, which is called smart[1], intelligent[2],or dynamic[3] street lighting system has been developed. It is emerged as economic investment plan and adopted by governments and municipalities to reduce energy consumption by switching the lamps ON/OFF at the right time; that also, it is dynamically switching the lighting level at each light point into light output required by the lighting standards at fixed time and/or based on the activity in the area [3-5]. Integrated Dynamic Street Lighting System (DSLS) are available in the world in many methods for more details[1-5]. One of these methods just need to install dynamic dimmer device in each LED luminary to increase and/or decrease the power and thus the light output. This device could be installed separately and/or integrated into the luminary; thus, no need for re-connecting the existing AC lighting systems network[4] like it is shown in Figure 1.

During last couple of years, significant amount of energy were consumed in Libya by street lighting sector about 3.996 TWh (19.4% of total consumption) In 2010[6] the thing which raised the level of attention and resulted in putting more efforts for saving more energy in this sector. In addition, few papers were found dealing with LED luminary in Libya [7][8], In [8]Replacing the high pressure sodium lamp system with LED lamp system saves 75% of energy and reduces the CO_2 emission by 75%[7]. Two proposals are investigated, the conventional lighting system and the solar powered LED lighting system. The cost, energy savings and the CO_2 emission of the two proposed systems are compared. The cost of the solar powered LED street lighting system is 1,250,200 LD, while the cost of the high pressure Sodium lamp street lighting system is 2,117,255 LD[8]. Also were found some researches dealing with ''dynamic street lighting systems", with several conditions as intensity of traffic, effects on perceived safety, raining or bad weather, and mingling the information technology (IT) and power. results of these researches show that it saves remarkable power as compared to conventional systems [1-5]. In [5] around 77%-81% reduction in power consumption can be achieved through this proposed automatic street lighting system for energy efficiency system design[5]. This paper will try to continue these efforts and to suggest two proposals:

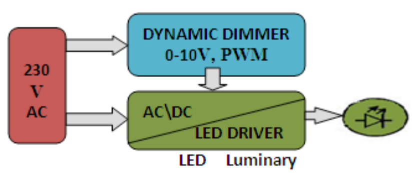

Figure (1). LED luminary layout with control node.

First proposal suggests the replacement of all old traditional HPS street luminaries with LED luminaries with keeping data analysis in order to find out the amount of electrical energy that could be saved. While, other proposal offers the integration of dynamic dimmer device (dynadimmer) into

LED luminaries as such method will save more time and less costs by integrating such technology into existing street lighting system with no need for changing the existing network. Data collected are to be analyzed in order to determine the amount of energy could be saved.

2. CONVENTIONAL STREET LIGHTING SYSTEM

This part represents data analysis of the normal pattern of energy consumed in street lighting sector. The analysis includes calculating the consumption average of lighting, average of lighting hours and annual rate of the total consumption. Data were obtained from General Electric Company (GECOL), and calculations will consider the following assumptions:

- The month is 30 days.
- The day is 24 hours.
- The estimated average of operating hours for each lighting pole is as shown in Table 1.

Table (1). Average operating hours.

Month	Time (from-to)	Dark (hours/day)
Jan	18 - 8	14
Feb	18.5 - 7.5	13
Mar	19 - 7	12
Apr	19.5 - 6.5	11
May	20 - 6	10
Jun	20.5 – 5.5	9
Jul	20.5 - 5.5	9
Aug	19.5 - 6	11.5
Sep	19 - 6.5	11.5
Oct	18.5 – 7	12.5
Nov	17.5 – 7.5	14
Dec	17.5 – 8	14.5
Total	142	
Average		11.8

The average operating hours for street lighting poles is found (11.8 hours).

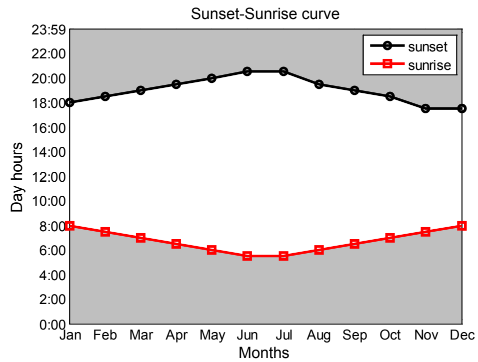

Figure (2). Monthly sunset and sunrise timing

According to the street lighting office in GECOL, the most widely bulbs used in the street lighting poles is HPS type, 450w and 281w, and the poles are divided into two types: single and couple poles, 23% of total street lighting poles are not working[9]. Table 2 shows the classification and working street lighting poles.

The total daily lighting energy consumption (TDC) in (KWh / day) can be estimated by the following equation [9]:

$$TDC = N \times \frac{\text{Lu min are (w)} \times \text{Average daily operating hours}}{1000} \quad \ldots (1)$$

Where:

N: is the total number of luminaries that equal to:

Total number of single poles + (2* total number of couple poles).

The annual lighting energy is given by [9]:

$$(ALE) = TDC \times 365 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; (2)$$

From the results obtained when use the date shown above and taking the average of energy consumption for each category of working street poles, Table 3 shows the TDC and ALE of energy consumption.

Table (2). Classification and working street lighting poles.

classification	single			Couple	Total
type	281W	450 W	Total	450 w	
All poles	122494	244995	367489	571654	939142
working poles	94324	188646	282970	440174	723144

Table (3). TDC & ALE for street lighting sector in libya.

Type		TDC (MWh)/ day	ALE (GWh)/ yr
single	281 w	312.759	114.157
	450 w	1001.710	365.624
couple	450 w	4674.647	1706.246
Total		5989.115	2186.025

If we take into account the value of losses in the distribution system through lighting system which was estimated at 7.5% [9], so the actual consumption rate as follow:

Total annual consumption

ALE (GWh/ yr) = ALE+ Losses (3)

Table 4 shows the value of losses in distribution system.

Table 4: Amount of losses in distribution system.

Losses (GWh)/ yr	163.951
Total Annual (GWh)/ yr	2349.976
Total Power (MW)	545.617

3. PROPOSAL SYSTEM CASES

The system proposed in this study consist of two cases; in the first case, LED lighting system is proposed to replace the HPS system.

The second case introduces how to apply the control node (dynamic dimmer) into LED in order to dim output lighting in streets. the two cases are described as follow:

3.1. first case :replacement hps with led system

This section of study discusses the results of replacing HPS luminaries with energy saving luminaries LED.

The calculations were based on replacing type (450W-281WHPS) luminaries with type (240W-160WLED) luminaries which give the same characteristics[9], and the results of (TDC & ALE) reached for both types are shown in the Table 5.

Table (5). TDC & ALE for streets lighting using led luminaries.

Type		Operating hours/day	TDC MWh/ day	ALE GWh/ yr
single	281HPS →160wLED	11.8	178.083	65
	450wHPS→240wLED	11.8	534.245	194.999
couple	450 HPS→240wLED	11.8	2493.145	909.997
Total			3205.473	1169.997
Losses GWh/yr			87.749	
Total Annual GWh/yr			1257.746	
Total Power (MW)			292.023	

3.2. second case: integrated dynamic dimmer in led system

This case presents how to save more energy through integrating electronic control node (Dynadimmer) into LED luminaries after being installed in replacement to HPS in street lighting system.

The Dynadimmer is a simple stand-alone smart control system designed for reducing energy consumption by using a variety of preset or custom dimming profile which requires no internal clock, additional wiring or controls.

The dynadimmer controls LED driver based on preprogrammed power levels, which is set up by the manufacturer or customer, for each day, taking into consideration the calendar graph.

The configuration is based on the midpoint of the time of the dynadimmer configured luminaries peaks, which is varied from summer to winter times.

The dynadimmer configured luminary will continuously calculate the midpoint of the evening based on its start and stop times; that is, this process is known as its dimming profile.

Dimming times schedule is configurable and downloadable via a programmer or USB PC cable, for more information see [10-11].

This study uses Philips dynadimmer product type (Custom–DCP Dynadimmer- different ways) [10] which can be configured to 5-time events (from T1 to T5) and 5-dimming levels (T1, T2, T4 and T5) with the later has one hour period of dimming time. For T3, it has four hours dimming time. The dimming levels for (T1, T2, T3, T4, T5) are 90%, 80%, 50%, 70%, 90% respectively (refer to Figure 3).

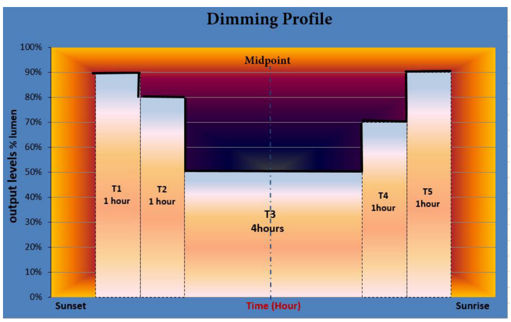

Figure (3). Dimming profile proposal.

Programmed dimming profile levels used in this study are compatible with GECOL standards (design standards adopted by GECOL, Oct 7, 2007) and with European standards (EN 13201 standards Nov 2003).

Table 6 shows the results reached from integrating dynamic dimmer into LED lamp used in street lighting system.

Fig 4 indicates the amount of energy that could be saved with using LED luminaries operated by dynamic dimmer device which put in replacement to traditional HPS luminaries. The figure shows that (47%) of the total energy consumed in the street lighting sector could be saved when traditional luminaries HPS are replaced with LED luminaries.

This amount of saved energy is increased by (11%) after integrating dynamic dimmer system into the LED luminaries.

Consequently, the amount of 58.72% of total energy consumed in street lighting sector could be saved.

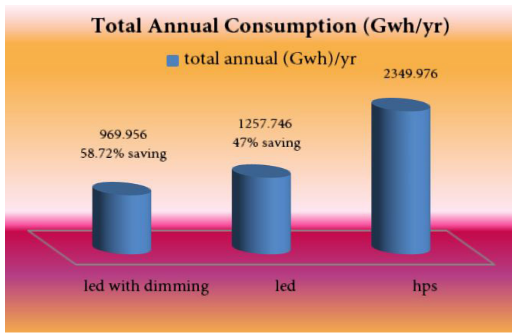

Figure (4). Total annual consumption GWh/yr by integrated dynamic system.

4. CONCLUSION

This study shows the benefits of using new technology and suggests that the replacement of traditional (HPS) with (LED) luminaries operated by intergraded dynamic dimmer device will result in saving significant amount of energy consumed in street lighting sector.

It indicates that an amount of 2349.976 GWh is consumed annually with use of (HPS) luminaries. This amount could be reduced by 47% to reach an amount of 1257.746 GWh annually, with capacity of 1092.23 GWh annually saved, by adopting replacement proposal.

On adopting both proposals (the replacement & integrating), the energy consumed in street lighting sector annually could be saved by %58 to reach 969.956 GWh, with an amount of 1380.02 GWh being saved annually.

Table (6). TDC&ALE for street lighting using LED with dynamic dimmer.

type HPS		Dc/luminaries (Kwh)/day			Tdc (Mwh)/day	ALE (Gwh)/yr
		LED	LED with dimmer 2h10%, 1h20%, 4h50% 1h30%			
single	281wHPS/ 160wLED	3.31	1.89	1.456	137.335	50.127
	450wHPS/ 240wLED	5.31	2.83	2.184	412	150.38
couple	450WHPS/ 240wLED	10.62	5.66	4.368	1922.68	701.778
TDC(Mwh)/day		5989.115	3205.473	2472.015		
ALE(Gwh)/yr		2186.025	1169.997	902.285		
Losses (Gwh)/yr		163.951	87.749	67.671		
total annual (Gwh)/yr		2349.976	1257.746	969.956		
Total power (MW)		545.617	292.023	225.204		

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