Energy Saving in Lightning Industry

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I. INTRODUCTION

Since a long time ago, man-made illumination became a substantial and integral part of our lives. Nowadays, there is no industry that would be fully functional without this illumination. Moreover, yearly consumption of light energy increases dramatically. As a result, the issue of energy saving in lightning engineering is very important.

About 180 milliards kW*h of electric energy is consumed in Ukraine yearly, where 15% of this energy is being used for illumination. Thus, the annual consumption of electric energy used for illumination is approximately 27 milliards kW*h.

The electric energy that is being used for illumination, in a global scale, is distributed this way: 28% - housing sector, 48% - service sector, 16% - industrial sector, 8% - street and other types of illumination.

Interestingly, Ukraine produces virtually the same amount of electric energy per capita compared to well developed countries; however, the consumption of this energy is extremely ineffective. Please refer to the table below (Table I) for specific indexes of light energy production and consumption in Ukraine and the world's leading countries.

TABLE I
INDEXES OF LIGHT ENERGY PRODUCTION AND CONSUMPTION

Name of index	Unit of measuring	Ukraine	Leading countries in the world
Production of light energy per capita	$\frac{Mlm*h}{pers.}$	30	85
Expenditures of electric energy on production of 1 Mlm of light energy	kW*h	36	20
Light energy that is generated by energy-saving discharge light bulbs	%	45	80-90
Per capita consumption of luminescent light bulbs	pieces/ppl*year	0,35	1,6
Per capita consumption of high-intensity discharge light bulbs of high pressure	pieces/ppl*year	0,03	0,3

II. POWER EFFICIENCY OF LIGHTING INSTALLATION

Power efficiency of the lighting installation (LI) is determined by the cost of light energy that is generated during the exploitation time and largely relied on electric energy expenditures. Cost indexes are distributed as the fallowing:

- lighting devices (LD) and sources of light (LS) expenses- 10.15%
- mounting and serving OP expenses - 15%
- Electricity charges - 70.75%.

There should not be a decline in the quality of electric energy that is used for illumination for economy reasons, since losses from this decline will considerably exceed the cost of the economized energy.

LI is considered to be efficient when it provides high-quality illumination, does not change its traits during the prolonged work and consumes a minimum amount of energy that is needed.

LI efficiency depends on:

- luminous efficiency of LS and their durability;
- parameters of light engineering and power technologies;
- stability of light bulbs' parameters during the exploitation period;
- number of hours that lighting installation was used per year.

In addition, it is important to take into consideration cost of light bulbs, lighting devices and their maintenance.

III. SOURCES OF LIGHT

There is a big difference in power efficiency and exploitation time in various types of LS. Discharge light bulbs (DLB) generate from 50 to100 times more light energy per 1W of consumable power when compared to the incandescent light bulb (IL). Basic characteristics of various LS are resulted in Table II.

It is beneficial to use energy-saving luminescent light bulbs with the power of 18, 36 and 58W and a retort's diameter of 26mm instead of traditional light bulbs with the power of 20, 40 and 65W and a retort's diameter 38mm in new LI.

The compact luminescent light bulbs have 8-10 times greater exploitation time and 5 times greater luminous efficiency in comparison with incandescence light bulbs. These statistics demonstrate the rational behind the need of wide introduction in a housing sector as well as commercial and public establishments of luminescent light bulbs. Compact luminescent light bulbs are small in size, have mounted electronic starting regulative vehicle and standard screw-thread socle (E27, E14). These characteristics make it possible to easily replace incandescent light bulbs with a power of 25...100W in lamps used mainly at home.

Due to the longer exploitation time, compact luminescent light bulbs sharply reduce service cost of LI. For example, let us assume that a shop uses light bulbs for about 3600 hours annually. The intervals between the planned light bulbs replacement will increase from 3.5 months to 33 months in a production area, and from 11-12 month to 109 month in everyday household when incandescent light bulbs will be replaced on the compact luminescent light bulbs.

Please refer to the Table III for comparative characteristics of compact luminescent light bulbs and incandescent light bulbs.

TABLE II

PARAMETERS OF MODERN SOURCES OF LIGHT FOR GENERAL ILLUMINATION

Type of source of light	Power, P, W	Luminous efficiency, η, lm/W	Index of colour rendition, R_a	Average exploitation time, τ, hours	Light energy produced during the exploitation time (per 1W)	
					Mlm× hours	Relative units
Incandescence light bulbs (ILB)	15-200	10-15	100	1000	0,013	1
Incandescence light bulbs with a halogen cycle (ILBHC)	20-50	To 30	100	4000	0,05	4
Luminescent light bulbs (LLB)	18, 36, 58	48 - 80	57-92	10000-12000	0,911	69
Compact luminescent light bulbs (CLLB)	5-57	65- 80	85	8000-15000	0,460	35
Mercury-arc light bulbs (MALB)	100-2500	50-54	40	12000-20000	0,632	48
Metal-halogen light bulbs (MHLB)	35-3500	66-90	80 -90	To 15000	0,960	94
Sodium light bulbs of high pressure (SLBHP)	30-1000	85 - 160	25-60	10000-25000	0,780	60
Light emitter diodes (LEDs)	0,2-1,0	To 20 (white.) to 50 (col.)	80	100000	0,980	75

TABLE III

COMPARATIVE CHARACTERISTICS OF COMPACT LUMINESCENT LIGHT BULBS WITH MOUNTED ELECTRONIC STARTING REGULATIVE VEHICLE AND SOCLE E27 AND RELATED INCANDESCENT LIGHT BULBS

Power P_l, W		Light stream $Φ_l$, lm		Luminous efficiency η, lm/W		Exploitation time τ, hours.	
ILB	CLLB	ILB	CLLB	ILB	CLLB	ILB	CLLB
25	5	230-235	250	9	50	1000	10000-12000
40	7	430-475	400	11-12	57		
60	11	730-800	600	12-13,3	55		
75	15	960-1030	900	12,8-13,7	60		
100	20	1380	1200	13,8	60		
100 (with Kr)	23	1500	1500	15	65,2		

It is very beneficial to use the discharge light bulbs of high pressure for external illumination in industrial premises with heavy conditions. Sodium light bulbs of high pressure, which became a replacement to the mercury-arc light bulbs, are one of the most effective sources of light. The luminous efficiency of this source of light is about 160 lm/W at power 30 - 1000W. Moreover, their exploitation term can exceed 25000 hours. The small sizes and high brightness of sodium light bulbs of high pressure allow them to be widely used in various light devices with concentrated light distribution. Sodium light bulbs of high pressure are often used for economic reasons where color intensity and recognition is less of an importance. Their warm yellow light can fully satisfies the needs for illumination in parks, roads, shopping centers, and for many case of decorative architectural illumination.

One of the advantages of modern sodium light bulbs of high pressure is their ability to deliver the small slump of light stream during the exploitation period. For instance, light bulbs with 400 W power make 10-20% during 15000 hours at the 10-hours cycle of burning. Please refer to the Table IV for the savings of electric energy that is due to the transition to more effective sources of light.

TABLE IV

POTENTIAL SAVINGS OF ELECTRIC ENERGY DUE TO TRANSITION TO MORE EFFECTIVE SOURCES OF LIGHT

Light source replacement	Average saving, %
ILB on CLLB	60 - 80
ILB on LLB	40 - 54
ILB on MALB	41 - 47
ILB on MHLB	54 - 65
ILB on SLBHP	57 - 71
LLB on MHLB	20 – 23
MALB on MHLB	30 - 40
MALB on SLBHP	38 - 50

III. STARTING REGULATIVE VEHICLES

When analyzing power efficiency of light sources it is necessary to take into account energy consumption of starting regulative vehicle (SRV) or ballast, without which given source of light will not be able to work. In general, typical electromagnetic SRV are widely used in inexpensive lamps.

The expensive lamps with mirror screening grates that are used for illumination of administrative bureaus, offices etc., use electromagnetic SRV.

Lately electronic starting regulative vehicles (ESRV) began to be widely used as SRV, especially for luminescent light bulbs. They work in the frequency range from 25 to 70 kGz. The task of ESRV is to provide a stable work of LLB. The usage of ESRV is very economically advantageous. When the losses of power in electromagnetic SRV consist of 15% of the power of light bulbs, the losses in ESRV do not exceed 10%. Furthermore, the high-frequency LLB result in the increase of their luminous efficiency, do not create acoustic noises and a light stream flickering, promote a power-factor complete of set LLB-SRV, allow to regulate the light stream of lamps.

The European Parliament established a directive with the requirements for the energy saving for the ballasts for luminescent light bulbs. On the one hand the SRV classification from the energy consumption point of view (classes A, B, C, and D) is executed, on the other hand, the order of removal from production and consumption of electromagnetic ballasts (D, C, B) is set. Thus, in a near future the countries of European Union will only use the electronic complete set SRV for luminescent light bulbs. In fact, «luminescent light bulb T5 - ESRV» can potentially be the most effective in terms of power and lightning technology points of view.

The data on the comparison of luminous efficiency of a complete set lamps luminescent light bulbs and various types of SRV are resulted in Table V - VII.

TABLE V

CHANGE OF LUMINOUS EFFICIENCY OF A COMPLETE SET LAMP SRV WITH STANDARD ELECTROMAGNETIC SRV

Power of light bulbs, P_l, W	Standard electromagnetic SRV			
	Total power of complete set, P_Σ, W	Light stream Φ, lm	Luminous efficiency η of complete set	
			lm/W	%
Standard LLB				
18	29	1450	50,0	100
2×18	23	1450	63,0	100
36	46	3450	75,0	100
58	71	5400	76,0	100
Compact luminescent light bulbs				
7	14	400	28,6	100
9	15	600	40,0	100
11	16	900	56,2	100
18	29	1200	41,3	100
24	35	1800	51,4	100
36	46	2900	63,0	100

TABLE VI

CHANGE OF LUMINOUS EFFICIENCY OF A COMPLETE SET LAMP SRV WITH ELECTROMAGNETIC SRV WITH LOWERED LIGHT LOSSES

Power of light bulbs, P_l, W	Standard electromagnetic SRV			
	Total power of complete set, P_Σ, W	Light stream Φ, lm	Luminous efficiency η of complete set	
			lm/W	%
Standard LLB				
18	24	1450	60,4	120
2×18	21	1450	69,0	110
36	42	3450	82,1	109
58	66	5400	81,8	107
Compact luminescent light bulbs				
7	11	400	36,3	126
9	13	600	46,1	115
11	15	900	60,0	106
18	24	1200	50,0	121
24	30	1800	60,0	116
36	42	2900	69,0	109

TABLE VII

CHANGE OF LUMINOUS EFFICIENCY OF A COMPLETE SET LAMP SRV ESRV

Power of light bulbs, P_l, W	ESRV			
	Total power of complete set, P_Σ, W	Light stream Φ, lm	Luminous efficiency η of complete set	
			lm/W	%
Standard LLB				
18	19	1350	71,0	142
2×18	18	1400	77,7	123
36	36	3350	93,0	124
58	55	5200	94,5	124
Compact luminescent light bulbs				
7	9	400	44,4	155
9	12	600	50,0	125
11	14	900	64,3	114
18	20	1200	60,0	145
24	27	1800	66,6	129
36	39	2900	74,3	118

IV. LIGHTS AND LIGHTINGS SYSTEMS

The correct choice of lighting devices and lighting systems at the beginning stage of lighting installations has important impact on energy saving. Lighting devices are chosen according to standard projects, lighting schemes and performance groups. The main role here is played by the curves of light forces, which is one of the main features of lighting devices. The efficiency of these curves of light force is determined by the L/H ratio, where L stands for distance between the lighting devices, H refers to the height position of lighting device over the lighting surface.

It is beneficial to use the lighting installation with slotted light in the explosive, dusty and premises with severe environmental conditions to receive approximately 10-15% energy saving.

When an asymmetric arrangement of equipment and its low density of distribution is present, it is beneficial to support with light the basic zone with less intensity than additional working in indoor areas. Potential saving of electric energy depending on the ratio of main and additional areas and normalized illumination to them is provided in Table VIII.

TABLE VIII

ECONOMY OF ELECTRIC POWER FROM CORRELATION OF BASIC AND ADDITIONAL AREAS

Attitude of additional areas toward a general area, %	Savings of electric power %
25	20 - 25
50	35 – 40
75	53 - 65

V. LIGHTING CONTROL SYSTEMS

Choice of lighting control systems depends on the size and type of a room where they will be used. The exploitation of automated devices of artificial lighting control according to the intensity of natural lighting is appropriate for rooms with square 50 m^2.

The usage of remote control to control lighting staircases, halls, corridors and other support facilities is appropriate. This allows us to disable a part of lamps at night time. The rules of evacuation lighting are executed.

The usage of control systems of artificial lighting results in up to 30 - 35% power savings.

VI. MEASURES TO IMPROVE ENERGY EFFICIENCY OF LIGHTING INSTALLATIONS

Energy efficiency of lighting installations that consequently reduce CO2 emissions during the first thermal power plants include:

- widespread adoption of energy efficient CLLB instead of ILB in lighting installations of residential and public buildings;
- transition of light devices with linear fluorescent light bulbs to the new generation of bulbs with 26 mm diameter (type T5) with high luminous efficiency to (105 lm / W) in lighting installations of industrial and public buildings ;
- using of ESRV instead of electromagnetic ballasts in CLLB and LLB;

- automated lighting control and management according to the intensity of natural light or with the presence of sensors;
- more efficient use of natural lighting with the active light distribution elements on light openings (both side and ceiling).

The energy saving data in the lighting industry is provided in Tables IX and X.

TABLE IX

POTENTIAL ELECTRIC POWER SAVINGS DURING THE ILLUMINATION PROCESS

Measure	***Economy %***
Transition on light bulbs with effective discharge light bulbs:	20-80
• using of energy saving LLB;	
• using of CLLB (at direct replacement ILB);	10-15
• transition from light bulbs MAL on light bulbs SLHP;	75-80
• raise of light bulbs stabilities descriptions (decline of coefficient of supply lighting installation)	50 20-30
Decline of energy loss in SRV:	
• application of electromagnetic SRV with the lower light energy losses for LLB;	30-40
• application of electronic SRV	70
Application of light bulbs with effective curves of light forces and high efficiency	15-20
Application of light devices with increased operating efficiency – decline of coefficient of supply (on 0,2-0,35)	25-45

TABLE X

ESTIMATION OF ELECTRIC POWER SAVINGS

Ways of saving	Estimation of potential savings %
Improvement of facilities of illumination	
• Expansion of production of effective sources of light and their application	14,0
• Increase of luminous efficiency of sources of light	6,0
• Rise in stability of descriptions of sources of light	3,0
• Rise of sources of light efficiency	6,0
• Improvement of operating properties of lighting devices	3,5
• Expansion of lighting devices production with the effective curves of light forces	3,0
• Decline of energy consumption of lighting devices, in particular due to the usage of ESRV	1,5-2,0
Improvement of methods of illumination	
• Expansion of application domain of the system of the common localized illumination	6,5
• Expansion of application of the systems of the combined illumination	4,0
• Rational using of natural light and systems of management by illumination	4,5-4,7

REFERENCES

[1] Справочная книга по светотехнике/ Под ред. Ю.Б.Айзенберга. – М.: Знак, 2006. -972с.

[2] Энергосбережение в освещении. Под ред. Проф. Ю.Б.Айзенберга. М.: Издательство “Знак”, 1999. – 264с.

[3] Рохлин Г.Н. Разрядные источники света. М.: Энергоатомиздат. 1991. – 720 с.

[4] Кожушко Г.М. Щодо концепції розвитку світлотехніки в Україні. //Світлолюкс . 2009. - №1.

[5] Трембач В.В. Световые приборы. М.: Высш. Шк. 1990. – 463 с.