Influence of the Loss of Voltage onto the Quality of Road Lighting

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Abstract – **The calculation of the lighting technical parameters of road lighting systems requires that the voltage tapping is accounted. Even when the voltage tapping is within the admissible standard values, the flood of light for Sodium lamps is established to be considerably decreased.**

Keywords – **Road lighting, Voltage drop, Voltage fluctuations, ICEST 2008.**

I. Introduction

In compliance with the Bulgarian National Standard (BNS) the working voltages of the electric distribution network are – 230/400 V. According to BNS EN50160 the voltage in the system may range from 92÷106% of the working supplying voltage of the consumers.

As it is known, the sections of the electric lines supplying the road lighting are calculated with admissible loss of voltage ΔU = 3%, which, in cases of direct supply from switchgear, is 5% correspondingly.

When the supplying voltage is reduced to within the range of 5%, the flood of light for the different lamps decreases to 80% of its nominal value. [1, 2]. This drop in the flood of light by value is approximately equal to the operation factor, which is about 80% with the well-maintained installations. Therefore, the 'voltage factor' is, due to its value, as important as the maintenance factor.

The tapping of the supply voltage has also effect on the color temperature of the lamp, the endurance of the lamp and the starting regulatory appliances and other basic parameters.

In addition, when the supply voltage increases sharply to above the ballast nominal, the power of the lamp set grows - ballast and consumption of electricity, endurance of the lamp and ballast considerably decrease but the risk of fire increases.

II. Calculation of the Loss of Voltage in the Road Lighting Electrical System

The calculations done are based on a particular example of road lighting system – city highway of class ME1, L_{av}=2,0 cd/m^2 with length of 700 m and width of m. The main road-bed consists of two road-ways of 10.50 m, each with thee lanes in one direction and dividing strip of 1.50 m. Sodium lamps of high-pressure (SLHP) are used as light sources: with power of 250W in the central part and 150W sideward.

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The supply of the road lighting system (RLS) is of three-phase by CBT-cable (Fig.1). The loss of voltage is calculated for the most loaded branch (that is №2). 17 lamps are connected to each phase R and S, and 16 – to phase T.

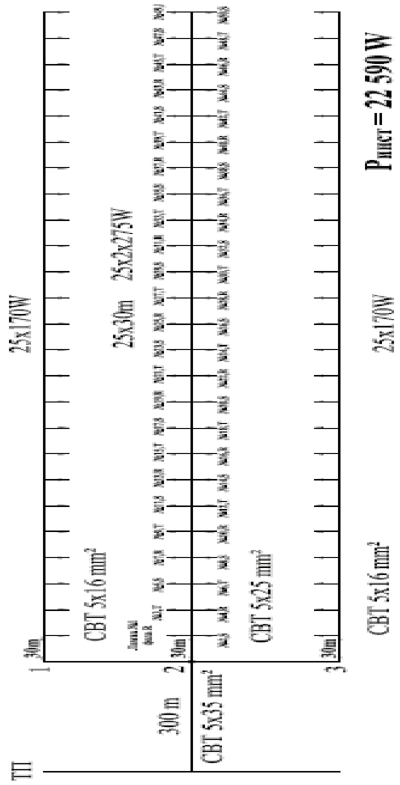

Fig. 1. Supply scheme of road lighting system

With such power, type and section of the cables and distance between the illuminators the loss of the voltage is calculated in two ways: 1) when reading just the active resistance of the electrical line and 2) when the inductive resistance of the line is taken into account. The second method enables the calculation of losses in three possible situations: **a)** without compensating inductive charge (cosφ =0.5); **b)** by compensation with individual capacitors (cosφ =0.9) and **c)** with electron starting-regulatory appliances - ESRA (cos φ =1).

Based on the calculations a conclusion can be drawn that when the 'power' of reactive resistance in the cables is ignored in simple calculation, the error is of **30%**. (ΔU = 4,60 % when the reactive cable resistance is read and 3,21% when it is not). This comparison is made for scheme with compensation (cos φ =0,9). When cos φ =1, the error between the two methods of calculations is **26%.**

Obviously, the second method is the right one since the really existing voltage losses in the inductive resistance of the line are not ignored.

The losses of the voltage in the line are least with ESPA (cos φ =1 and least losses of power) if we compare the results obtained by the method with reading the reactive component and different cos φ. ESPA provide for stable parameters of the lamp with tapping of the supply voltage within the range ±20%.

III. Analysis of the Effect From the Voltage Loss onto the Light-Technical Parameters of the Road Lughting System

For the example given above, the loss of the voltage is calculated and the effect of this loss onto the flood of lamp light is defined. The brightness of the road is also fixed. We shall see in details the calculations with phase R and cos φ = 0,9 .

Experimentally I studied the effect of the tapping of the voltage on the parameters of the lamps of different discharge [1]. On the basis of the procession of the experiment results, the studied dependences from the electrical network voltage are best described with polynom of second degree:

$$Y = A_0 + A_1 .U_m + A_2 .U_m{}^2, \qquad (1)$$

where:

Y – electricity of the lamp (**I_l**) , power of the scheme (**P_{sh}**), lighting of the lamp (**E_l**) measured in the spherical photometer or voltage of the lamp (**U_l**);

A_0, A_1 and A_2 are coefficients whose values for SLHP 250W are pointed in Table I.

TABLE I

SLHP 250W	A_0	A_1	A_2
I_l	1,22	0,00465	0,0000174
P_{sh}	861,3	- 9,01	0,0278
E_l	6724,5	- 112,22	0,55
U_l	675,74	- 6,42	0,0167

The electrical and light-technical parameters of the lamps for fixed values of voltage above and below the nominal may be defined through the so suggested analytical dependencies.

The loss of voltage to every lamp and its supply voltage are calculated. The values of the flood of light, the electricity and power are estimated through (1). For example, for the first lamp № 1 it was calculated that the loss from the switchgear to it was 2,83 % or 6,23 V. That means that lamp № 1 shall not have supply voltage of 220 but (220-6,23) V = 213,77 V. Likewise for the other lamps supplied from phase R.

The results obtained are given in Table II.

TABLE II

SLHP 250W	**Um, V**	**Φ, lm**	**I, A**	**P, W**
№ lamp	220	31100	3,000	250
1	213,77	29533	3,009	205,62
4	213,31	29418	3,003	204,31
7	212,88	29312	2,998	203,09
10	212,48	29213	2,993	201,96
13	212,11	29121	2,989	200,92
16	211,76	29035	2,984	199,97
19	211,45	28958	2,981	199,10
22	211,16	28889	2,978	198,31
25	210,90	28823	2,975	197,61
28	210,67	28766	2,972	196,99
31	210,47	28717	2,969	196,44
34	210,30	28676	2,967	195,98
37	210,16	28641	2,966	195,60
40	210,04	28612	2,965	195,30
43	210,96	28592	2,963	195,06
46	209,90	28577	2,962	194,91
49	209,87	28569	2,961	194,84

From Table II and Fig.2 it is seen that with loss of voltage calculated so far to ΔU = 5% the flood of light decreases by 5,04 % at the third lamp, **5,8%** at the fourth and **8%** at the last one.

It must be taken into account also that in the course of exploitation, due to the fast aging (drop in the flood of light) of the lamps at the beginning of the electrical circuit (higher voltage) and slower aging at the end of the electrical circuit (lower voltage), the state of decrease in the flood of light along the electrical circuit becomes worse. If not timely maintained for the faster aging, the result shall be fusing of the lamps at the beginning of the electric circuit. With increase in the loss of voltage in the electrical circuit the differences in the aging speed shall become bigger.

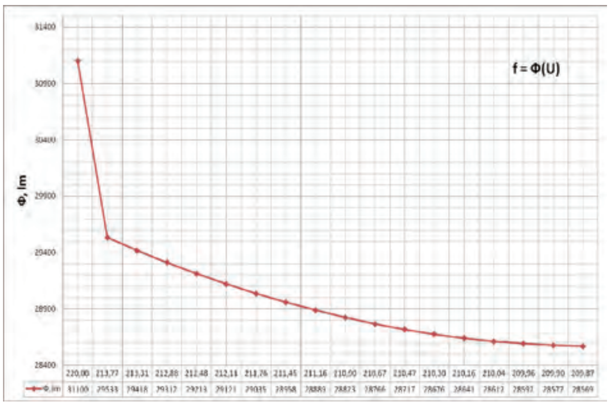

Fig. 2. Dependency of the flood of light on the supply voltage

IV. Analysis of the effect From the Voltage Loss onto the Change of the Brightness for the Road in the Specified Road Lighting System

For the example set the average norm brightness is $L_{n\,av} \geq 2 cd/m^2$. The calculated value of L_{av} has to be $\geq 2{,}5\ cd/m^2$ where maintenance factor is = 0,8. With such disposition of illuminators (the area between stairs - 30m and height 14m), type and power of the lamps the brightness is set at $L_{av} = 2{,}5\ cd/m^2$ (Fig. 3).

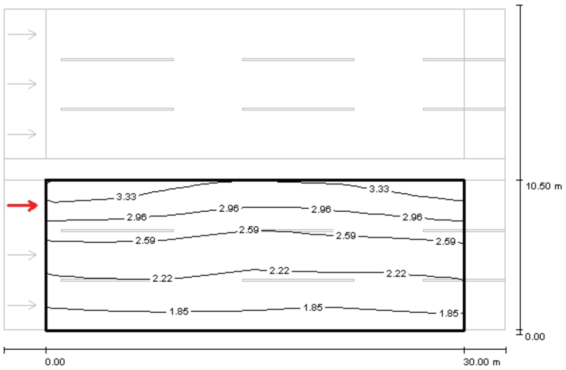

Fig. 3. Brightness onto the road

For SLHP and admissible loss of voltage $\Delta U_a = 5\%$ we report the so called 'factor of voltage' - 0,87 [2]. The average brightness is $L_{av} = 2{,}5 * 0{,}87 = 2.175\ cd/m^2$.

The entire examination shows that installations with 'big' losses of voltage are of low quality not only due to considerable decrease of the flood of light, the change of the brightness and evenness, but also due to the expensive maintenance. If group changing of the lamps is undertaken with such installations, more than half of the lamps must be changed far too early. This also means that with installations of big difference in the supply voltage of illuminators there must be undertaken partial or separate change of the lamps.

V. Conclusion

Considerable decrease in the flood of light are established in the Sodium lamps of high-pressure (SLHP) even where the tapping of voltage is within the admissible standard values. Therefore, when designing road lighting systems it is suggested that the flood of light of SLHW is increased in accordance with the tapping of voltage for every line.

The exact calculation of the loss of voltage (by reading of the reactive resistance of cables), is also a very important factor.

Stabilizers of voltage and special ballast with terminals of lower and higher values of SLHP-supply voltage must be used.

In the lighting devices there must be used ESRA allowing tapping of the supply voltage without changing the flood of light of the lamps. The means of gradual regulation of the flood of light and brightness of the road is another considerable advantage.

References

[1] Ivanov Z. A., Effects of mains voltage variations on discharge lamps, XII National conference "Light 2004", 15-17 June 2004, Varna , Bulgaria.

[2] K. Vajdič, Pad napona potpuno zanemaren factor kvaliteta javnog osvetljenja, , Osvetljenje 96.

[3] Application guide to HID lamp control gear, Philips Lighting, 01/95.

[4] Effects of mains voltage variations and dimming on High Intensity Discharge lamps (HID), Philips Lighting, 01/96.