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VARIATION OF ELECTRICAL PARAMETERS OF TWO PUBLIC LIGHTING SOLUTIONS DUE TO CONTINUOUS DIMMING OF LIGHT OUTPUT

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Abstract: Public lighting applications, including street and pedestrian lighting provide crucial services for human safety, productivity and comfort in the modern urban and suburban landscape. However, energy charges for these lighting applications represent the largest part of all expenses for public lighting. The increasing price of electricity is, by itself, responsible for the majority of the increase in streetlight operation budgets.

Telemanagement systems that control public lighting networks offer a significant opportunity to save energy and decrease the impact of artificial lighting on the environment. When high intensity discharge lamps are used regulation of light flux can be achieved using either step-dimming or continuous dimming ballasts (1-10V, DALI).

This paper presents the variation of electrical parameters of two lighting solutions due to continuous dimming of light output. The first solution consists of a high pressure sodium SON-T 150W lamp and the electronic DynaVision SON ballast. The ceramic metal halide CDO-TT 150W lamp and the electronic DynaVision CDO ballast represent the second studied solution. Both solutions use the 1-10V analogic protocol technology for continuous dimming of lamp light flux.

The results are presented as a comparison of the influence of light output dimming on the electrical parameters of the two solutions. This comparison is defined in terms of active and reactive power consumption, current harmonics and power factor values.

Key words: Electrical parameters, continuous dimming, light output, public lighting

1. INTRODUCTION

Modern public lighting provides many benefits to the community both in terms of safety and security of the citizens, as well as economically. Public safety involves reducing road accidents at night and reductions in street crime and the fear of it. Also by highlighting architectural assemblies using proper lighting techniques, the city can become an attraction for many visitors leading to tourism development.

Globally an estimated 218 TWh of electricity was consumed by outdoor lighting in 2005, amounting to about 8% of total lighting electricity consumption. From this, street and roadway lighting used about 114 TWh of energy globally while illumination of car parks is responsible for the consumption of 88 TWh of electricity in the same year [1].

In Europe there are 80 million street lights consuming about 60 TWh per year. According to some European Initiatives like the European project "E-street" 63.7% or 38 TWh of energy consumption in outdoor lighting could be saved by implementing intelligent systems like adaptive street lighting and the use of LEDs [2].

2. TELEMANAGEMENT SYSTEMS AND LIGHT OUTPUT DIMMING

Currently street lighting control systems range from simple to complex structures. In order to describe these control systems different terms have been used over the years such as telemanagement, adaptive, dynamic and intelligent.

A telemanagement system enables the lighting system to automatically react to external parameters like traffic density, remaining daylight level, road constructions, accidents or weather circumstances. The operating costs of public lighting systems can be lowered if the critical data needed to make better planning and operation decisions can be cost effectively collected. However this design can be implemented only using a suitable network that can gather the information and can exercise control. Today power line based communication networking can achieve significant operating and energy cost savings while improving both the reliability and the quality of public lighting systems [3].

Maintaining the same illumination intensity for a pre-defined period is not an optimal solution. There is no need for the same light intensity if there is very little traffic and a clear sky. Regulation of the light level by dimming the light output of the lamp based on the desired situation is the main function of any telemanagement system.

High intensity discharge lamps can be dimmed using either step-dimming or continuous dimming technologies. When electronic ballasts are used the dimming level is set by an external module that communicates with the ballast's control interface. The main control interfaces are 1-10V, DALI and proprietary interfaces.

Ballasts with 1-10V input dim the light output according to the voltage level of there set point input in a range of 1-10 volts, where 10 volts means maximum level and 1 volt means minimum level [3]. To switch the light on and off the power to the ballasts is interrupted using a relay.

3. ANALYSIS OF THE MEASUREMENTS RESULTS

The increasing use of non-linear equipment (electronic power converters, discharge-type lighting, etc.) in electrical distribution systems has raised the level of concern about the effects of these loads on the system [4].

From the point of view of lighting equipments of special concern are single-phase devices with rectifier front-end power supplies (electronic lighting ballast) and discharge lamps.

This study analysis two lighting solutions used nowadays in public lighting applications. The first solution consists of a high pressure sodium SON-T 150W lamp and the DynaVision SON 1-10V electronic ballast. The ceramic metal halide CDO-TT 150W lamp and the electronic DynaVision CDO ballast represent the second studied solution. Both solutions use the 1-10V analogic protocol technology for continuous dimming of lamp light flux.

The high pressure sodium lamps are very energy efficient and last up to four eyes. The lamp is optically efficient but has a long run-up time. Also it has limited color rendering and provides a orange/yellow light.

Metal halide lamps are based on newer technology and trends in public lighting. They are energy efficient and provide a high quality white light. These lamp types offer significant environmental advantages because of very low mercury levels and high energy efficiency [5].

The 1-10V electronic ballasts used are controllable ballasts that expect an external signal to switch or set a dim level.

In order to determine the variation of electrical parameters for the studied solution, a series of measurements were conducted. These measurements also help to recognize the problems that these equipments cause to its electrical environment surrounding in different working regimes due to continuous dimming of light output. The experimental setup is presented in figure 1.

Fig.1 - Experimental setup

The setup consists of a Fluke 43 power quality analyzer (used for the analysis of single-phase systems), an autotransformer, a PC station, a constant voltage source and the SON and CDO solutions. Also a luxmeter was used to determine the relation between the light level and power level at different values of the control voltage. Figure 2 presents the experimental setup scheme.

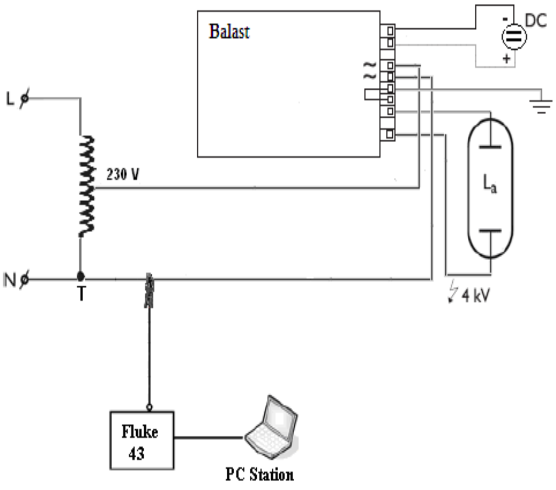

Fig.2 - Experimental setup scheme

A series of 20 measurements were made for each solution by lowering the DC control voltage by 0.5V steps using the constant voltage source. Table 1 presents the RMS values of the current fundamental as well as the level γk of the main current harmonics for the two studied solutions related to voltage control, while the waveforms and harmonic current analysis are presented in figures 3, 4, 5 and 6.

Table 1. The level of current harmonics related to the value of the control voltage

DC control voltage [V]	SON-T solution				CDO-TT solution			
	I_1 [mA]	γ_3 [%]	γ_5 [%]	γ_7 [%]	I_1 [mA]	γ_3 [%]	γ_5 [%]	γ_7 [%]
10	701	7	4	2	702	7	5	2
9.5	704	8	5	1	703	7	5	1
9	694	7	5	1	684	7	6	2
8.5	670	8	5	1	663	7	6	1
8	645	8	4	2	643	8	6	1
7.5	617	8	5	2	616	8	6	1
7	590	8	5	2	588	8	6	2
6.5	565	8	5	2	554	8	6	2
6	531	9	5	2	521	9	6	2
5.5	500	9	6	2	489	9	6	2
5	466	10	6	2	460	9	6	2
4.5	434	10	6	3	418	10	6	2
4	424	10	6	3	388	11	7	2
3.5	420	10	6	2	359	12	7	2
3	411	10	7	2	325	13	8	2
2.5	404	10	7	2	291	13	8	2
2	400	11	7	2	256	15	9	3
1.5	398	11	6	3	222	17	10	3
1	391	12	6	3	223	17	10	2

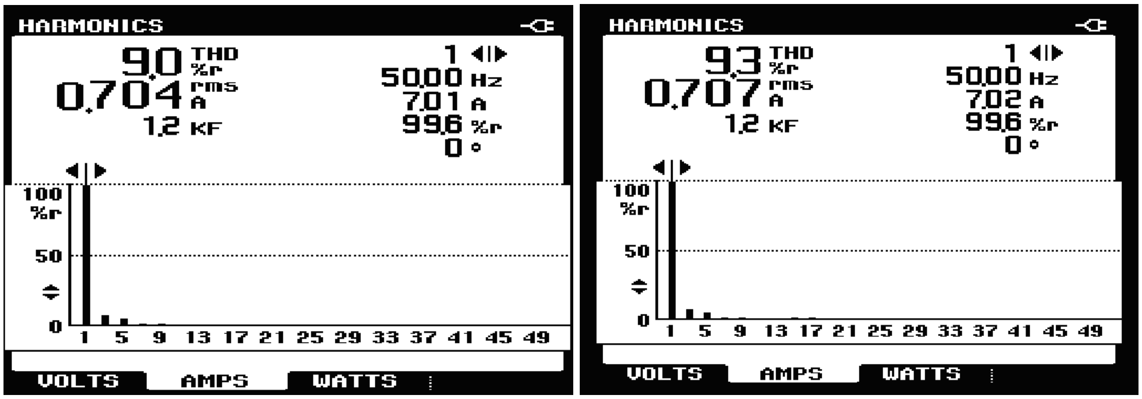

Fig.3 - Harmonic current analysis (Ucontrol = 10 V) : left – SON-T solution; right – CDO-TT solution

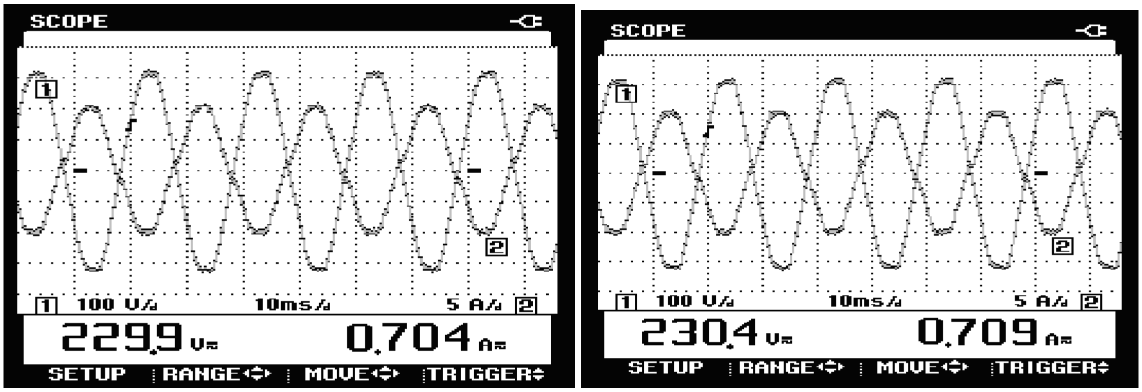

Fig.4 - Waveforms (Ucontrol = 10 V, 1 – Supply voltage, 2 – Input current) :
left – SON-T solution; right – CDO-TT solution

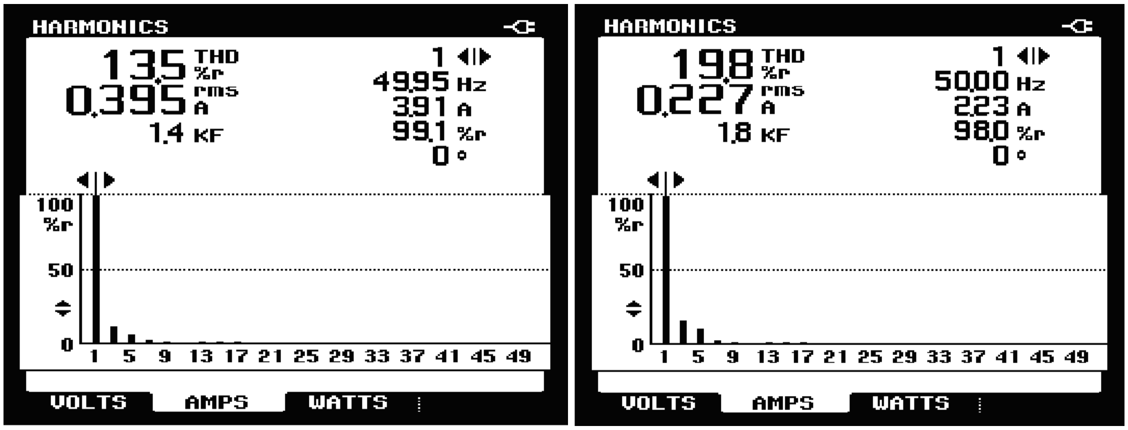

Fig.5 - Harmonic current analysis (Ucontrol = 1 V): left – SON-T solution; right – CDO-TT solution

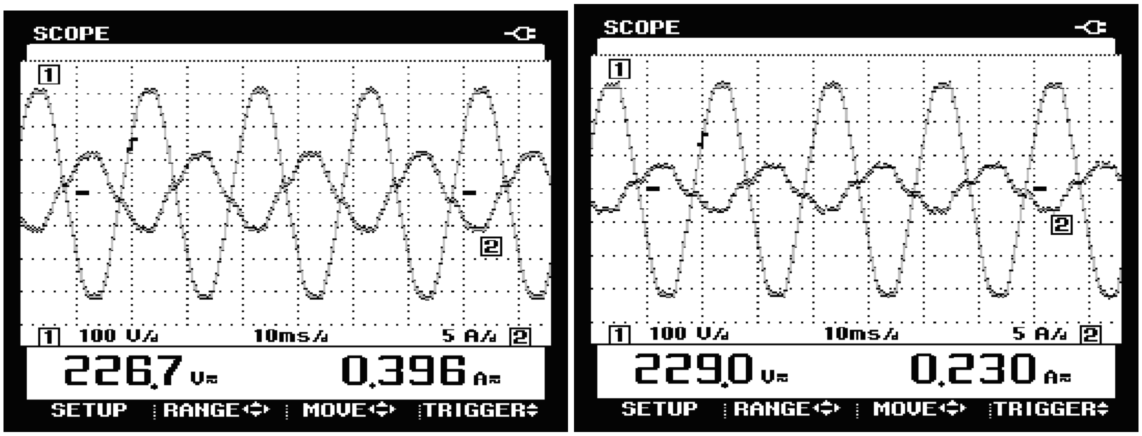

Fig.6 - Waveforms (Ucontrol = 1 V, 1 – Supply voltage, 2 – Input current) : left – SON-T solution; right – CDO-TT solution

As it can be observed the current harmonic spectrums reveal a low-harmonic content. In the case of the first solution the level of the 3rd harmonic is between 7-12%, the level of the 5th is between 4-7% while the level of the 7th harmonic is between 1-3% of the fundamental over the 1-10V control voltage interval. Measurements result for the second solution have shown that the level of the 3rd harmonic is between 7-17%, the level of the 5th harmonic is between 5-10% while the level of the 7th harmonic is between 1-3% of the fundamental over the 1-10V control voltage interval.

The parameter that best quantifies the harmonic pollution introduced by these lighting solutions is the current harmonic distortion factor (THD). Figure 7 presents the variation of the values of current distortion factor over the 1-10V control voltage interval. The values obtained are between 9-13.5 % in the case of the SON solution, 9% corresponding to the maximum control voltage (10V) while a value of 13.5% for the THD was obtained for the minimum control voltage (1V). In the case of the CDO solution these values ranged between 9.3% (10V) to 19.8% (1V).

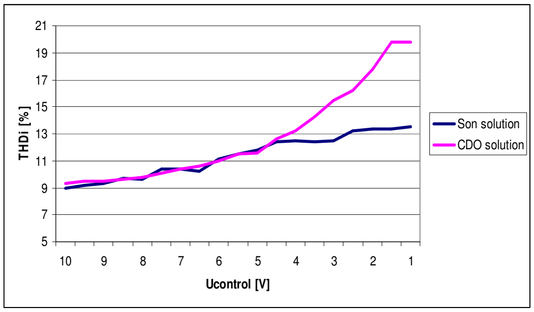

Fig.7 - Variation of current THD

The variation of power factor was also studied. Figure 8 presents the results of the measurements over the 1-10V range.

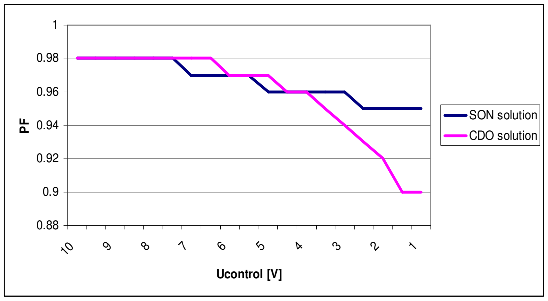

Fig.8 - Variation of power factor

Another aspect that was studied is the variation of active and reactive power for the two solutions over the same 1-10V control voltage.

As can be observed, the active power consumption at maximum control voltage is around 160W for both solutions. However, the measurements have revealed that around the lower range of the control voltage the active power consumption is different for the studied solutions.

The minimum value for the SON solution is 85 W which corresponds to 53% of nominal power while the minimum value for the CDO solution is 48 W which corresponds to 30% of nominal power. However, it is not recommended to dim metal halide lamps under 50% of their power because this reduces life expectancy. The results are presented in figure 9.

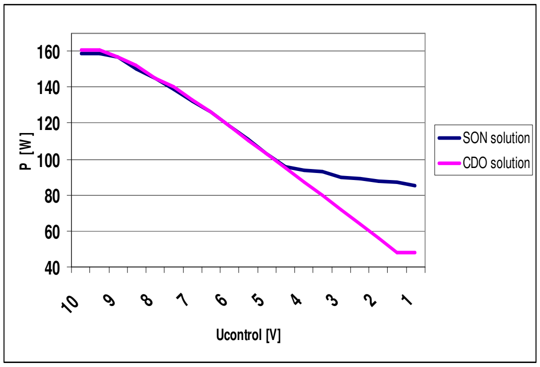

Fig.9 - Variation of active power

In terms of reactive power it can be concluded based on the measurements results that the variation is limited between 25-30 VAr for the first solution and 20-27 VAr for the second solution. The results are presented in figure 10.

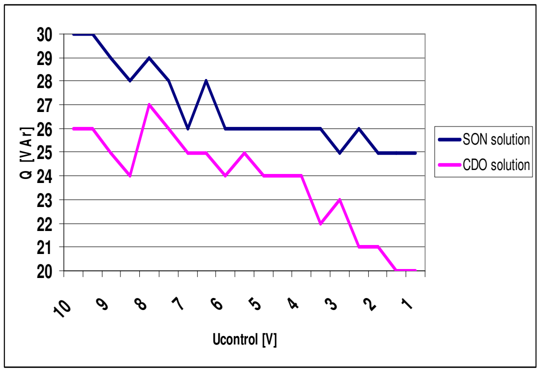

Fig.10 - Variation of reactive power

As has been mentioned above a luxmeter was also used in order to measure the light output in order to provide an overview of the variation of light output, luminous efficacy and power consumption related to the value of the control voltage. Figure 11 presents the results for the SON solution while the results of the CDO solution are presented in figure 12 in relative values.

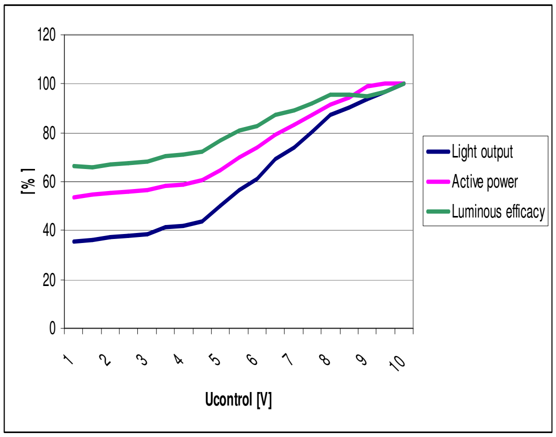

Fig.11 - SON solution: variation of light output, active power and luminous efficacy

The luminous efficacy is the ratio of luminous flux to power or in other words a measure of how well a light source produces visible light. As it can be seen from figures 11 the luminous efficacy of the SON solution drops from 100% to 66% over the 1-10V control voltage range but these values are in general higher then those of the CDO solution (100% to 45%) presented in figure 12.

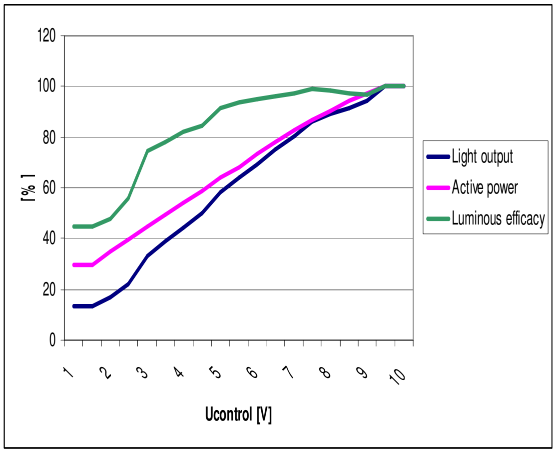

Fig.12 - CDO solution: variation of light output, active power and luminous efficacy

4. CONCLUSIONS

This paper presents a comparison between the variations of the main electrical parameters of two public lighting solutions used nowadays, due to the influence of continual dimming of light output. The dimming technology uses the 1-10V analog protocol and the two dimmed lamps are high pressure sodium and ceramic metal halide lamps.

Based on the analysis of the measurement results a number of conclusions can be made:

- The dominant current harmonic is 3rd for both lighting solutions. The levels of the 3rd ,5th and 7th harmonic are in the limits imposed by the standard for electromagnetic compatibility [6] for lighting equipments (class C) over the entire 1-10V dimming range;

- The current harmonic distortion factor (THD) varies between 9% (minimum for both solutions) to the maximum value of 13.5% for the SON solution and approximately 20% for the CDO solution.
- In terms of power factor variation it was observed that the SON solution presents a higher power factor then the CDO solution in the lower part of the control voltage range. In both cases a relation can be made between the lower values of the power factor and the increasing values of current harmonic distortion factor. This is due harmonic pollution introduced by these equipments;
- The active power consumption drops almost linear in both cases related to the control voltage with an advantage for the CDO solution (down to 30% of active power). However lamp manufacturers do not recommend and do not guarantee the proper function of metal halide lamps when dimmed under 50% of power. Variation of reactive power consumption is insignificant in both cases;
- From the point of view of luminous efficacy, as a parameter of energy efficiency, it can be concluded based on the results obtained from the measurements that the CDO solution is more efficient in the 2.5-10V control voltage range. Under this value the luminous efficacy of this solution drops drastically and the SON solution is more efficient.

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