

Experimental Analysis of Advanced System for Reducing the Energy Consumption of Public Street Lighting Systems

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Abstract - The paper presents an experimental method for measurement of the performances of an advanced control system used in public street lighting systems. It is presented the hardware implementation of dimm light advanced system and the measurement analysis of this system using a Lab VIEW application. By use of the dimm light control of the public street lighting system we increase the power efficiency and quality of lighting level, and, in the same time, the costs are decrease.

Key-Words: Public street lighting, dimm light system, measurement system, power efficiency.

1 Introduction

Lighting accounts for 25% of the total electric energy produced, and improvement in efficiency of lighting appliances would surely ease energy consumption. The public lighting is one of the quality criterions of the modern civilization. The outdoor lighting is one of the power consumer where the light-technical, energy, economic and esthetical aspects have to be analyzed together, important being yet the lighting level on traffic road and pavement.

One solution that could open new development trend in the public street lighting is to make use of the advanced system for controlling the switch of street lighting [1], [4].

The new intelligent equipments used in this paper to increase the efficiency of the public street lighting include more functions: switch on/off depending on the local lighting state; the possibility of switch on/off depending on the functioning preliminary schedule; the knowledge from distance of the functioning state of the respective electric network, the signaling at the appearance of some possible defects; the possibility of remote controlling the switch on/off commands; the knowledge possibility from a central point of the energetic consumptions in each switch on point and the state of the respective network, especially that the measured quantities are most often non-sinusoidal; the

possibility of establishing economic functioning regimes, inclusive at voltages lower than nominal voltages; the endowment with a distance transmitting device of the command and measuring information: radio, wireless etc.

Dimmability is desirable for various applications that would also contribute to the reduction of power dissipation as lighting requirements may not require full intensity all the time [2],[8]. Ones of these new functions can be implemented using hardware and software specialized elements, such as programmable automats DIMM Light with the ZDM 3500/3000/2500/2000 family.

This paper proposes the introduction of an advanced control system which uses the programmable automat DIMM Light, and which leads an automat system for control the switch in public street lighting systems. It is presented the hardware implemented application and the measurement analysis method of the performances of proposed system using a Lab VIEW application.

2 Dimm light system configuration

In practical application we use the ZDM 2500 device of DIMM Light (Figure 1), for controlling a public street lighting system which contains 10 sodium vapor lamps, each of lamp has the nominal power 250W. To configure the DIMM Light innovative solution for the application related to the control of switch on points in public street lighting, we take into account the next requirements:

- connecting the automat consumer, depending on the lighting state, through the agency of a solar radiation transducer or through manual command;
- connecting the lighting network using an hour program, depending on the day from the week;
- supplying the network through the agency of voltage/frequency converter;
- supplying the lighting through the agency of an autotransformer, in order decrease the lighting intensity between certain hours (the reduction of the luminous flux).



Fig. 1. The DIMM Light device family ZDM 3500/3000/2500/2000.

The ZDM 2500 has a simple installation and a simple programming with a computer or laptop. The input analogical signals, received from the twilight transducer are compared with the values imposed in the lighting controller. Depending on this comparison the automat will decide if it's the moment to command the connection of the public street lighting. Depending on the chosen automation system, autotransformer or converter, the current and voltage protections automatically modify their working parameters. The automation working in the autotransformer variant is realized when at ones of the input of ZDM 2500 a digital signal is applied. The working takes place when three signals are simultaneously applied with the programming clock signal. With the help of this clock we can program the period in which the luminous intensity will reduce (between what hours and what days). Thus, during the night, we can cut off light totally or cut off light partially with 50%, 33% or 67% of the lighting level.

The automation functioning with the help of the frequency converter is realized when at the input a digital signal is applied to the integrator blocks [3],[6].

3 LabVIEW application

The virtual instrumentation (VI) represents the association between flexible hardware equipment (data acquisition systems or programmable measurement instruments) attached to a microcomputer and an software which implements the functions of the instrument and represents the interface between the human operator and the instrument [7]. VI transparently combine computer resources, measurement and control possibilities of the hardware equipment (electric signal transducers, signal conditioning circuits, A/D and D/A converters e.a.), data analysis software, data processing, result presentation and process leading. In LabVIEW, the VI is a module developed through the programmer. It consists of an interface with the user ('front panel'-the front part of the instrument's panel) and a block program (the part behind the panel, the diagram, which is available only to the programmer). VI emulates a classical measurement instrument but they are much more flexible, a simple change is enough to reproduce another instrument with the same physical system. Organizing the program module with VI offers to the users a strongly graphical oriented interface, easy to use, which offers high accuracy and flexibility [5]. To proves the technical and economical advantages of the DIMM Light control system we design and implement a Lab VIEW application, shown in Figure 2.

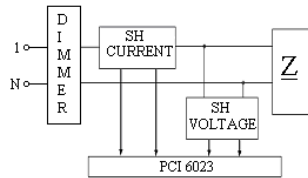


Fig.2. The LabVIEW application

4 Analysis of the measurements results

In order to consider the Lab VIEW application in our laboratory the load consists in a 250 W sodium vapor lamp with capacitor for discharge lamp circuits. First step of the measurement method is to consider the lamp without the ZDM 2500-DIMM Light device. In this case, we make the measurements for the current and voltage at the lamp terminals (shown in Figure 3a), for the power factor (shown in Figure 3b), and for the active power (shown in Figure 3c).

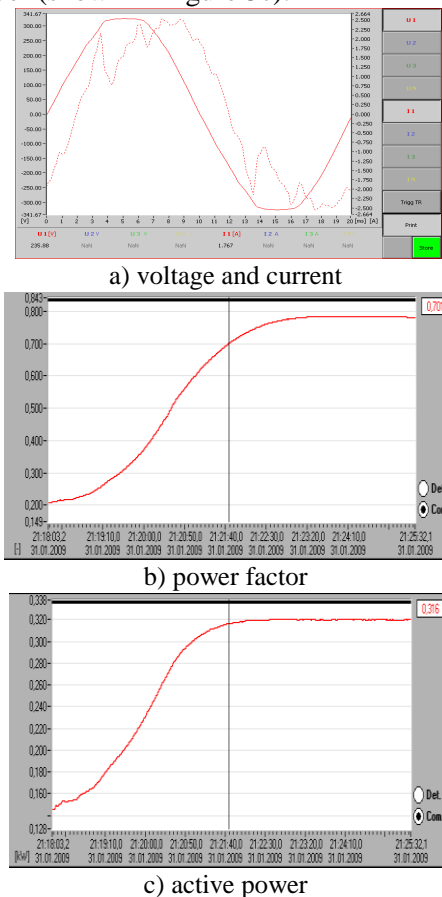


Fig.3. Results without ZDM 2500-DIMM Light

In the same time we implemented a Fourier method analysis for the voltage and current measurement, shown in Figure 4.

Second step in the measurement analysis method is to know the behavior of the DIMM Light. The variation of the current and voltage at the input of ZDM 2500 device are normally for the steady-state electro-energetically system.

For the output device measurements, we choose two different practical situations of public street lighting systems:

i) the lighting level is normal, consequently ZDM 2500 device hasn't an action, and the variation of voltage and current are shown in Figure 5;

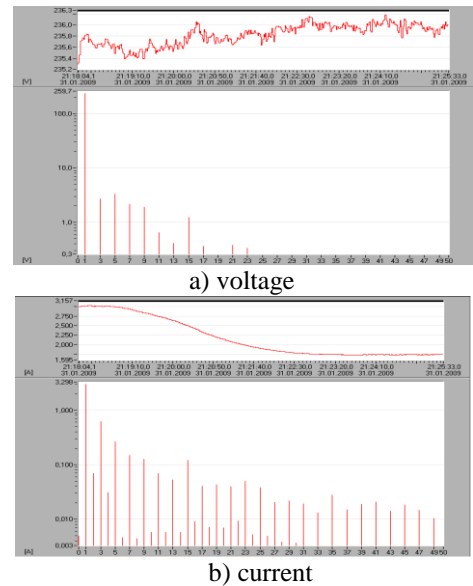


Fig.4. Fourier analysis without ZDM 2500-DIMM Light.

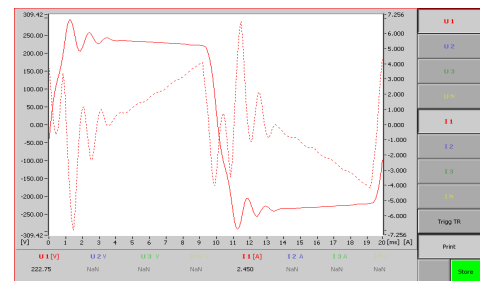
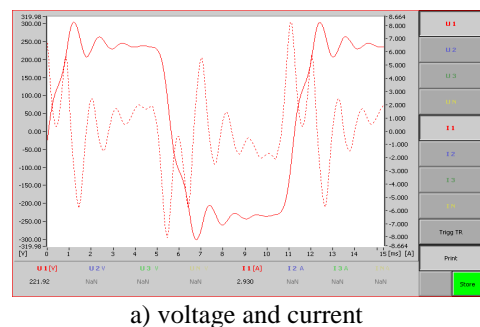


Fig.5. The variation of current and voltage at the ZDM 2500-DIMM Light when the reduction of the lighting level is 0%.

ii) the lighting level is cut off partially the with 67% by the ZDM 2500 device of DIMM Light, and the variation of outputs are shown in Figure 6



a) voltage and current

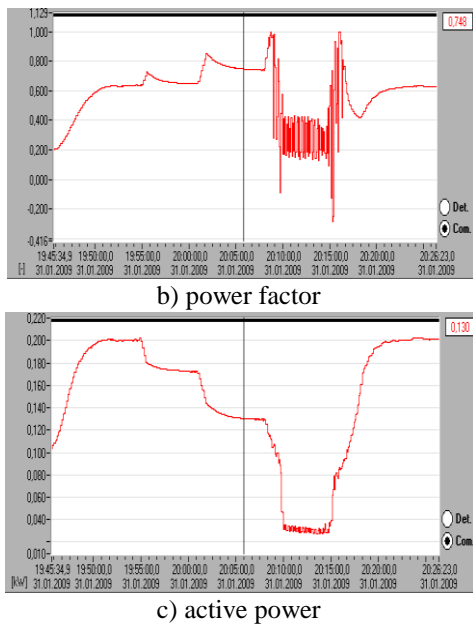


Fig.6. The variation of outputs at the ZDM 2500-DIMM Light when the reduction of the lighting level is 67%.

Other important measurements consist in the analysis of the variation of power factor and absorbed active power. We can observe an important variation of power factor (Figure 6b) which decreases when the autotransformer of the device starts to work and cuts off partially the lighting level. The active power has the same variation, shown in Figure 6c, so it decreases when the lighting level is partially cut off.

The case ii) is analyzed by using the Fourier transform, and their results are shown in Figure 7.

Generally, we can express the voltage and the current at the device ZDM 2500-DIMM Light output by using the Fourier series, so that

$$u(t) = \sum_{p=0}^m U^{(p)} \sqrt{2} \sin(p\omega t + \varphi^{(p)}) \quad (1)$$

$$i(t) = \sum_{p=0}^m I^{(p)} \sqrt{2} \sin(p\omega t + \varphi^{(p)} - \gamma^{(p)}) \quad (2)$$

where m is the finite number of harmonics considered, $U^{(p)}$ and $I^{(p)}$ represent the RMS values of the p^{th} -harmonic of voltage and current, respectively, while $\varphi^{(p)}$ and $\varphi^{(p)} - \gamma^{(p)}$ represent the phase angle of the p^{th} -harmonic of voltage and current, respectively.

The distortion of the voltage, especially in case b), compared with the voltage at the lamp terminals during the absence of the ZDM 2500-DIMM Light device, can be observed. In case b) the content and the amplitude of voltage harmonics increase: new even harmonics appear, and the amplitude of odd and even harmonics are with 10-50% bigger.

A similar observation can be extracted by analyzing the current variation. The amplitude of current harmonics are bigger, especially with the current at the lamp terminals during the absence of the ZDM 2500-DIMM. Thus new even harmonics appear, and the amplitude of odd and even harmonics are with 20-60% bigger. The distortion of voltage and current characteristics when the ZDM 2500 device cuts off the lighting level with 67% is explained through the existence of the non-linearity of the autotransformer in this device.

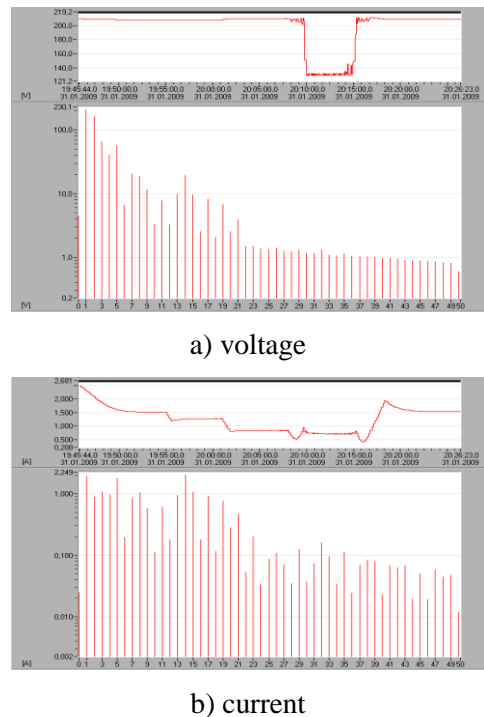


Fig.7. Fourier analysis at the ZDM 2500-DIMM Light outputs when the reduction of the lighting level is 67%.

In conclusion, when the lighting level is cut off partially with 67%, the ZDM 2500-DIMM Light reduce the power factor and the absorbed active power with 30%, but the device introduces a distortion at the current and voltage.

In the final step, the LabVIEW application we made the comparative measurements of the lamp parameters: illuminance (lighting level), current, and the absorbed active power in two situations, without ZDM 2500-DIMM Light, and in presence of ZDM 2500-DIMM Light when this device cuts off partially the lighting level of lamp with 0%, 20%, 40%, and 67%.

The illuminance (E) of the 250 W sodium vapor lamp decreases (Figure 8) when the ZDM 2500-DIMM Light cuts off partially with 0%, 20%, 40%, and 67% the lighting level. In the absence of the device the maximum value of E is 3580 lx, and when ZDM 2500 cuts off partially the lighting level with 0%, 20%, 40%,

and 67% the values of E are respectively 2280 lx, 1820 lx, 1103 lx, and 275 lx (shown in Table 1). The opinion polls showed that this demand-orientated brightness controlling for these limits of the illuminance in public street lighting is accepted by the local communities and the residents.

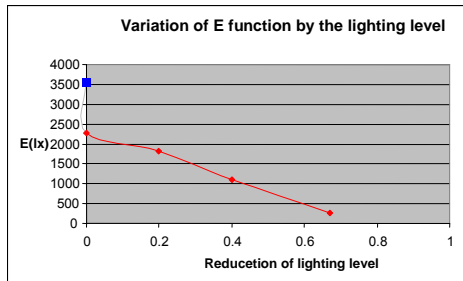


Fig. 8. The variation of the illuminance of lamp when ZDM 2500-DIMM Light cut of partially 0%, 20%, 40%, and 67% the lighting level.

The efficiency of ZDM 2500-DIMM Light results if we compare the values of the current and the absorbed active power in the absence of the device and when the device works.

Table 1

Lamp 250W	without DIMM	with DIMM	with DIMM	with DIMM	with DIMM
Reducing of lighting level	0	0%	20%	40%	67%
E(lx)	3580	2280	1820	1103	275
I(A)	1.73	1.51	1.27	0.82	0.7
P(W)	320	200	173	130	32

The variations of current and absorbed active power are shown in Figure 9, and their values are presented in Table 1.

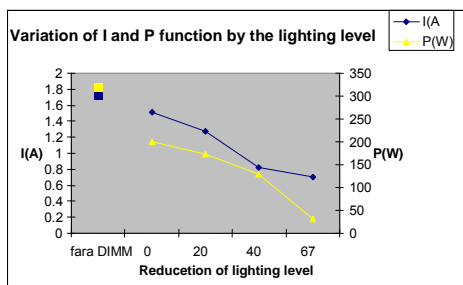


Fig.9. The variation of current and absorbed active power when ZDM 2500-DIMM Light cut of partially 0%, 20%, 40%, and 67% the lighting level.

In the absence of the device the nominal current of lamp is 1.73 A. We can observe an important decrease of current when the ZDM 2500 is connected in circuit

compared with the nominal current, between 87.2% and 40.4%. In the same time a strong decrease has the absorbed active power. The nominal value without ZDM 2500 is 320 W and, when the device is connected in circuits, the absorbed active power is smaller, with values between 62.6% and 10%.

4 Conclusion

By use of the DIMM Light for controlling the street lighting system we increase the power efficiency and quality of lighting level, and in the same time the economic results are better.

It obtains an essential reduction of performance and energy costs (more than 30%), the device has a simple installation and programming, the amortization in less than 5 years.

References:

- [1] Robert S. Simpson, *Lighting control-technology and applications*, Focal Press, 2003
- [2] *** *Dimm Light*, ISLE and KD Elektroniksysteme GmbH, 2008G.
- [3] H. M. Al-Rahmani, G.F.Franklin, A new optimal multirate control of linear periodic and time-invariant systems, *IEEE Trans. Automat Control*, AC-35, pp.406-414, 1990
- [4] S. D. Grigorescu, C. Cepisca, I. Stancu, Modern Solution, related to ICE Standards for electronic ignition and supply of discharge lamps, *Proc. Electric Lighting International Show 1998*, Bucharest, pp. 25-30.
- [5] H. Andrei, C. Cepisca, G. Chicco, L. Dascalescu, V. Dogaru, F. Spinei, LabVIEW Measurements in Steady State Nonsinusoidal Regime , *WSEAS Transactions on Circuits and Systems*, Issue 11, vol. 5, pp. 1682-1685, Nov. 2006.
- [6] Cepisca,C, Andrei,H, Grigorescu,S, Perpelea,M, Stancu,L,Dogaru,V, Computerized expert system for lighting grid, *Proceedings of the 7th WSEAS International Conference on Circuits, Systems, Electronics, Control and Signal Processing*, pp.133-138, Puerto de la Cruz, Tenerife, Spain, December 15-17,2008, WSEAS Press
- [7]****LabVIEW Reference Manual*,National Instruments, 1998.
- [8] M.H.Rashid, *Power Electronics Handbook*, Academic Press, 2006
- [9] W. Chang, Characterizing harmonic currents generated by fluorescent lamps in harmonic domain, *IEEE Trans. Power Del.*, vol. 20, no. 4, pp. 1687-1689, Oct. 2003.