Analysis of Electric Energy Consumption for Domestic Lighting

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1. Abstract

Experimentally collected data of electric energy consumption for domestic lighting in Serbia is presented and analysed in this paper. Measurement has been done on the City of Nis representative sample. Measuring devices for experimental evaluation of the residential lighting consumption have been developed. Devices were placed close to the electric light sources in each location of the representative sample, in order to store time of the electric light source state changing in their internal memories (eeprom). According to the measured results a statistical analysis is presented.

2. Introduction

Lighting is present in every household and represents a considerable share of the electric energy consumption in the residential sector. Most people are not aware that many types of traditional lamps they use have very low efficiency and that installing more energy efficient lamps, could save large amount of energy and money. Considering the potential for saving energy, reducing pollution and preventing climate change many projects have been realised in the last fifteen years [1 - 5]. These studies have resulted in a number of polices and programmes adopted to reduce lighting consumption [6, 7].

One of the studies is Domestic Efficient Lighting (DELight) [1] which incorporated data on domestic lighting all over Europe, focusing on European Union, with in-depth analysis of three countries: Germany, Sweden and UK. Beside the analysis of electric energy consumption for residential lighting the research has also been done on potential energy savings from changing incandescent bulbs with compact fluorescent lamps (CFLs). The investigation, reported by International Energy Agency (IEA), has shown that lighting in the residential sector consumed 811 TWh of total electric energy in 2005. This amounts to about 31% of total lighting electric energy consumption and 20% of total electric energy consumption in the residential sector [4]. In the EU-15 Member States the lighting consumption, as share of the total residential electric energy consumption, ranges between 8% and 23% (if water and space heating are excluded from residential electric energy consumption) [3]. On the other hand the average consumption per household in EU ranges from 300 kWh/month (Portugal) to 1143 kWh/month (Sweden) [3]. Compared to EU countries average consumption per household in Serbia is 400 kWh [8].

In order to determine lighting electric energy consumption of residential sector in Serbia measuring devices for experimental evaluation have been developed. Devices were positioned close to each luminaire of the representative sample, in order to store time of the electric light source state changing in their internal memories (eeprom). Analysing

experimentally collected data daily duration of lamp operating time as well as number of switching on/off operations for each location are obtained. Based on the obtained results and total ELSs wattage it has been estimated which part of total electric energy consumption is consumed by ELSs. Finally, optimal selection of CFLs for different locations is proposed, and potential energy savings from changing the incandescent bulbs with CFLs is estimated.

3. Methodology

In order to measure electric energy consumption for residential lighting, small, simple and cheap measurement units were developed. The measuring unit, shown in Fig. 1, contains microcontroller PIC12F675, eeprom 24LC128, battery, phototransistor LTR-4206, oscillator 32.768kHz, resistors and capacitors. Phototransistor with narrow sensitivity diagram is used in order to obtain valid data of switching on/off of the ELS and avoid wrong measurements due to presence of daylighting. Sensitivity diagram of the phototransistor is shown in Fig. 2.

Measuring devices are positioned close to luminaires in that way to avoid actuating device by daylight. Examples of measuring devices positions are shown on Fig. 3.

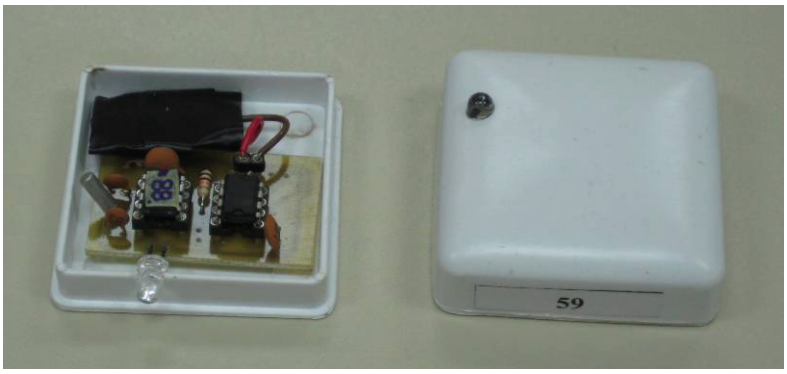

Fig. 1: Measuring units

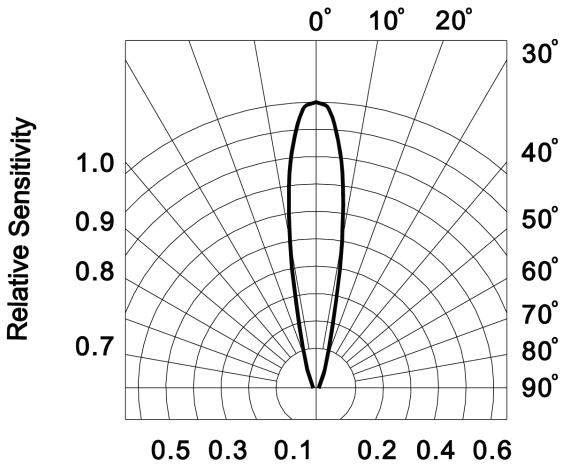

Fig. 2: Relative sensitivity diagram of phototransistor

Fig. 3: Examples of positions of the measuring devices

4. Results

A measurement has been performed in seven residential places located in surroundings of the downtown of the City of Niš, the second largest city in the Republic of Serbia, with total of 51 measuring places. Measuring devices have collected data between May and August, period when daylight is present the most, which should be considered in the analysis. It is planed to continue with measurements and to cover all four seasons during the year in order to have more precise picture of lighting consumption. During the measuring period Sunrise was between 4:52 am and 5:22 am, while Sunset was between 7:55 pm and 8:17 pm.

Measuring units are placed in living room, bedrooms, children rooms, kitchen, dining room, bathroom, toilette and hallway.
In living room two cases are considered:

I General lighting (ceiling mounted) and additional lighting (torchiere, lamp) is installed;

II Only general lighting is installed.

Total number of considered luminaires and number of different ELS types for each location are shown in Table 1. Table 1 also contains average wattage per location for each ELS type as well as wattage range.

Table 1. Number of luminaires with ELS type and wattage by location.

Location	No.	Incandescent		CFL		Halogen	
		No.	wattage	No.	wattage	No.	wattage
Living room I - ceiling	4	4	112 (100-150)				
Living room I - additional lamp	4	2	58 (40-75)	1	24	1	100
Living room II	2	2	160 (120-200)				
Bedroom - dressing room	5	4	74 (50-100)			1	50
Children room	5	5	128 (40-200)				
Kitchen	7	6	105 (75-150)	1	20		
Dining room	5	2	180 (180)	3	21		
Bathroom	6	6	85 (60-100)				
Toilette - WC	3	3	83 (75-100)				
Hallway	8	8	89 (40-120)				

Table 2. Number of switching on/off and daily duration of lamp operating time

Location	Daily number of switching operations		Daily operating time hours:min	
	Range	Average	Range	Average
Living room I – ceiling	0.5 - 3.8	1.9	0:30 – 0:55	0:37
Living room I -additional lamp	0.6 - 4.2	1.7	0:20 – 2:55	1:50
Living room II	2.1 – 2.6	2.4	3:30 – 4:10	4:00
Bedroom -dressing room	2.2 – 5.8	3.6	0:22 – 1:30	0:43
Children room	0.7 – 6.7	3.2	0:20 – 3:20	1:10
Kitchen	2.7 – 7.7	4.4	0:30 – 0:54	2:10
Dining room	0.7 – 2.6	1.7	1:10 – 1:40	1:20
Bathroom – Toilette	12 – 19.3	15.3	1:25 – 5:50	3:10
Toilette	6 – 10.7	7.7	0:40 – 3:30	1:37
Hallway	1.6 – 11.4	4.8	0:30 – 6:00	2:00

Table 3. Number of locations by daily lamp operating time

Duration	< 1 h	1 h – 2 h	2 h – 3 h	3 h – 4 h	4 h – 5 h	> 5 h
Number of measuring locations	19	15	6	7	1	3

Daily number of switching on/off operations and daily operating time of ELSs for each location are shown in Table 2. Table 3 shows ranges of daily operating time and appropriate number of locations for each range.

Average installed wattage of all luminaires is 705 W per household. During the peak demand period (between 8 pm and 10 pm) average operating wattage is 135 W (113 W – 185 W) what is around 20% of total installed lighting power. For representative sample average electric energy consumption of household was 440 kWh per month for the considered period. Average monthly lighting electric energy consumption was 47 kWh.

5. Conclusions

As it can be seen from Table 2, the greatest number of switching on/off operations is noticed in bathrooms and toilets while the longest average daily operating time is noticed in living rooms, bathroom, kitchen and hallway. Long operating time in hallways and bathrooms is due to low presence of daylight in those premises.

Out of 51 luminaires on which measurement has been performed daily usage of four luminaires is longer then 4 hours, while on seven places it is between 3 and 4 hours.

Based on measured data the lighting consumption per household is 10.75% as share of the total residential electric energy consumption of 440kWh. This percentage is less then in other EU countries, but great presence of daylight during the period of measurement should be considered.

Taking into consideration installed lighting wattage per household as well as consumer's habits to use mainly CFL of 20W, with additional change of two incandescent ELSs by CFLs installed wattage will be reduced for about 20%. The same benefit (of about 20 %) will be in lighting electric energy by randomly changing incandescent ELSs by CFLs, which is benefit of 100 kWh annually per household. Annual energy saving that would be achieved by substituting two ELSs per household is estimated to be 260 GWh considering that Republic of Serbia consists of 2.6 million households [9]. Taking into account that during the peak demand period (between 8 pm and 10 pm) average operating wattage per

household is 135 W, it can be concluded that the power demand in the same period would be less for about 70 MW on the Republic level by random substitution of two CFLs per household. These benefits would be greater if the selection of the locations for ELS substitution is done properly.

Acknowledgement: Authors would like to acknowledge Department of Lighting Engineering of the Technical University Ilmenau as well as LiTG e.V. (Deutsche Lichttechnische Gesellschaft) whose support made possible presentation of this manuscript at the Lux Junior 2007, Dörnfeld, Germany. Authors also thank the MS of the Republic of Serbia.

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