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Investigation and comparison of energy quality parameters for fluorescent and led light sources

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ABSTRACT

Fluorescent and LED lamps are the most common used light sources both in homes and offices due to their low energy consumptions. However both sources are short of the quality of power factor, harmonic components and colour rendering. Taking these parameters in account, the purpose of this study is to investigate and compare energy quality parameters for different light sources used with lighting control, especially dimming control. To that end, energy quality parameters as harmonic current values, total harmonic distortion and power factor of LED and fluorescent lamps in lighting control, under different scenarios and dimming are measured, analysed and suggestions made to evade the disruptive effects both on electricity network and local lighting control system.

Keywords: lighting energy savings, energy quality, current harmonics, power factor

Flüoresan ve led aydınlatma kaynaklarının enerji kalitesi parametrelerinin incelenmesi ve karşılaştırılması

ÖZ

Flüoresan ve led lambalar, düşük enerji sarfiyatları sebebiyle, evlerde ve ofislerde kullanılan en yaygın aydınlatma kaynaklarıdır. Bununla birlikte her iki kaynağın güç faktörü kalitesi, harmonik bileşenleri ve renk işlemeleri düşüktür. Bu çalışmanın amacı, farklı aydınlatma kaynaklarında aydınlatma kontrolü yaparak, özellikle karartma (dimleme) kontrolü, enerji kalitesi parametrelerini incelemek ve karşılaştırmaktır. Neticede, Led ve flüoresan lambaların, farklı senaryolarda ve dimlenerek yapılan aydınlatma kontrolünde ölçülen ve analiz edilen harmonik akım değeri, toplam harmonik distorsiyon ve güç faktörü gibi değerlerin ışığında, elektrik şebekesi ve lokal aydınlatma kontrolü sisteminde yıkıcı etkilerini önlemek için önerilerde bulunulmuştur.

Anahtar Kelimeler: aydınlatma enerji tasarrufu, enerji kalitesi, akım harmonikleri, güç faktörü

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1.INTRODUCTION

Lighting energy is the easiest parameter of the formula to gain energy efficiency and energy saving, numerous studies are held about lighting all over the world. There are several ways to obtain energy saving in conventional lighting systems such as changing ballasts and/or luminaries, adapting these systems to control interfaces, using ligting scenarios or reactive power compensation.

In-depth analysis of International Building Research Establishment (BRE) publication of Energy Consumption Guide [1] and Chartered Institution of Building Service Engineers' (CIBSE) previous reports [2], it is seen that 20 – 40% of worldwide building energy consumption is directly related to artificial lighting systems. Governmental buildings in USA are responsible more than one thirds of national electrical energy consumption and 25 – 40% of this value is due to artificial lighting energy consumption [3].Statistics about Canada show that 10% of institutional electrical energy consumption is directly related to lighting installations [4]. Nonresidential annual lighting energy consumption in European Union is about 160 TWh and 40% of this consumption is originating from buildings' artificial lighting systems [5].

As global energy consumption increases dramatically and lighting energy saving steps forward as the most possible way to save electrical energy, both scientific and commercial studies focus on lighting more than ever. Unfortunately lighting energy efficiency and saving issue is a two edged sword. Obtaining savings in lighting energy both new LED technologies and transition methods cause disruptive effects on energy quality parameters. Even if dimming strategies used Total Harmonic Distortion (THD) and Harmonic current (THD_I) ratios, power factor (PF) values are distorted significantly. Mentioned energy quality parameters are regulated by IEC and EN with various standards [6-8].

In this study under different scenarios and dimming THD_I and PF values are measured, analysed for different systems and all results are compared.

2. EXPERIMENT

Two experiment rooms are assigned for this study by the Electrical and Electronics Engineering Department of Sakarya University. Room 1is on the third floor of a four storey Engineering Faculty building, M-6. longitude. The surface areas of the identical test roomsare24 m^2, and they have each one window oriented to the northwest. Since the windows may have glare because of the daylight penetration, thin film covers used on the window glasses. Light transmissivity of the windows are measured as 67 %.Northwest-facing window is 1.5 m x 1.2 m and has a total area of 1.8 m^2. The effective window area is 1.2 m^2 according to the related IEA Task 21 report; similarly, the effective window height is 1.5 m [9].

Figure 1. Test Room 1 (LED)

Figure 2. Test Room 2 (Fluorescent)

Room 2 is on the ground floor of a three storey engineering faculty building, M-4. The surface area of the test room is 36 m^2, and it has one window oriented to the northwest. Northwest-facing window is 2.45 m x 1.75 m and has a total area of 4.29 m^2. The effective window area is 3.52 m^2 according to the related IEA Task 21 report; similarly, the effective window height is 1 m [1]. The ceiling of the test room is white, the walls are cream, and the floor is light brown. The ceiling height of the test room is 2.85 m. An artificial lighting system of the room is recessed in the suspended ceiling, consists of 8 special production double parabolic mirror louver luminaries; each one has two identical 58 W fluorescent lamps. Fluorescent lamps have 4000 K of colour temperature and 5200 lm luminous flux. Light transmissivity of the windows are measured as 89 %.

Existing artificial lighting system (Six 4x18 T8 fluorescent, double parabolic mirror louver luminaries) of Room 1 (R1) is changed with a LED system occupied with 1x41 W mid-range LED panels (Six 60 cm x 60 cm LED panels). In Room 2 (R2) existing system's ballasts are dimmable electronic ballasts (DALI ballasts). Each room's system is capable of dimming. R1 uses DALI featured LED drivers of Philips (92% eff, pf=0,95) and R2 uses Osram DALI Basic RC lighting automation system. R1 artificial lighting system provides 510 lux illuminance under 100 % operation and R2 system provides 1250 lux.

Electrical parameters, such as voltage, lamp currents, active – reactive powers, total harmonic distortion (THD, THDI) and power factor are measured and stored every 5 seconds with an electric energy analyzer (Janitza UMG 503). Total energy consumption forR1 is measured as 250.2 Wh and 1030Wh for R2 at 100% operating.Both lighting systems are adjusted to 5 different dimming levels.

Table 1. Dimming Levels of Lighting Systems

Level Name	Dimming Level (%)	Operating Level of Luminaries (%)
DL1	0	100
DL2	25	75
DL3	50	50
DL4	75	25
DL5	95	5

3.EXPERIMENT RESULTS

DuringtheexperimentperiodEnergy Analyzer UMG 503 recorded the measurements. Using these measurements THD_I and power factor values of each room are calculated (Figure 3-7). As seen on Table 3 LED panels' energy quality results are better than Fluorescent luminaires' results. Especially THD_I values are quite satisfactory.

Table 2. ExperimentResults

Level Name	Dimming Level (%)	Operating Level of Luminaries (%)	R1 LED THD_I (%)	R1 LED PF	R2 FL THD_I (%)	R2 FL PF
DL1	0	100	21.7	0.94	25.1	0.97
DL2	25	75	24.92	0.89	32.05	0.88
DL3	50	50	29.02	0.84	37.98	0.81
DL4	75	25	33.21	0.79	44.23	0.74
DL5	95	5	37.60	0.75	49.99	0.65

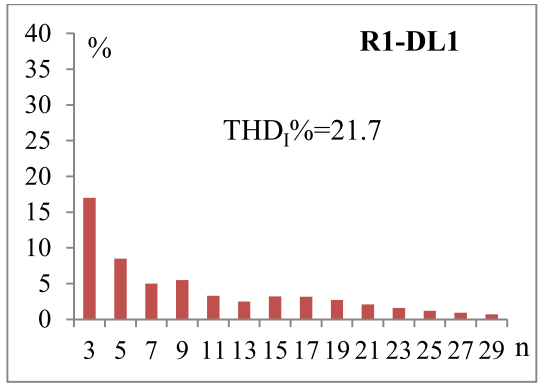

Figure 3. R1-DL1 scenario THD_I% results

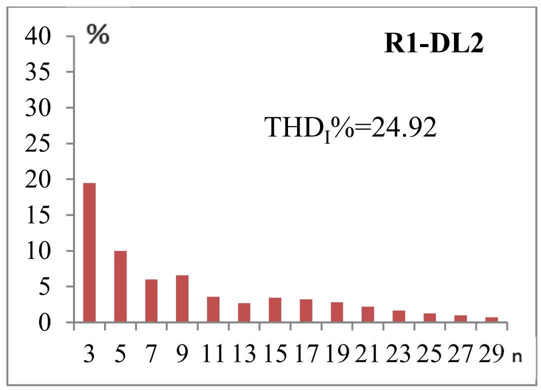

Figure 4. R1-DL2 scenario THD_I% results

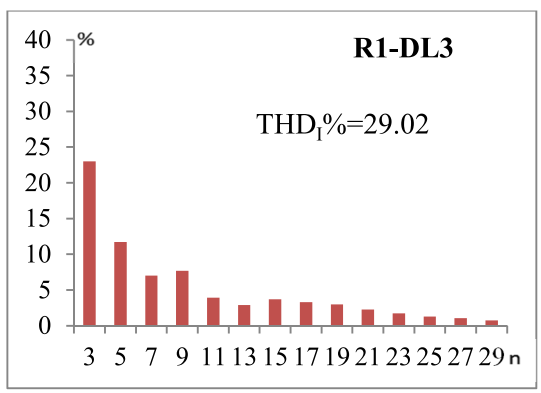

Figure 5. R1-DL3 scenario THD_I% results

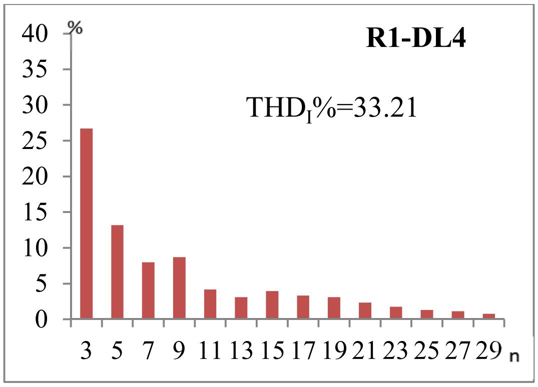

Figure 6. R1-DL4 scenario THD$_I$% results

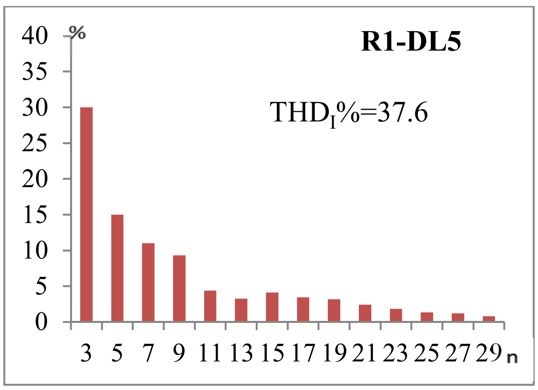

Figure 7. R1-DL5 scenario THD$_I$% results

Formulas used for calculation of THD_I and PF are given as follows:

$$THD\,(\%) = \frac{1}{I_1}\sqrt{\sum_{n=2}^{\infty} I_n^{\,2}} \tag{1}$$

$$PF = \frac{\cos\varphi_1}{\sqrt{1+THDi^2}} \tag{2}$$

4. CONCLUSION AND SUGGESTIONS

As seen inexperiment results both conventional and new artificial lighting systems have advantages and disadvantages in classical type of operating. Changing conventional ballasts of fluorescent luminaries with DALI ballasts and controllers might be a solution in the means of energy saving. Unfortunately energy saving is not the only issue has to be solved. Distortion of power quality parameters in the course of energy saving is a significant disadvantage. Similarly new technology products, LEDs, have this disadvantage, too. LED lamps and luminaries save greater amounts of electrical energy but, they also distort the energy quality parameters.

Using active filters integrated with DALI ballasts in lighting systems can be a logical solution to eliminate the harmonics and power factor distortion. Active Filters that have voltage source inverters are recently used in place of compensation systems in electrical installations. As previous studies indicated [12], adaptation of this equipment to lighting devices can lower the THDI and PF values. Onlyproblem seems like researches shall study on how to minimize the dimensions of active filters and integrate them with LED drivers and/or ballasts.

Pulse Width Modulation (PWM) can also be a solution. PWM is a modulation technique that conforms the width of the pulse, formally the pulse duration, based on modulator signal information. So adjusting the waveform of the load current and estimating it to the sine-wave form can help to lower the distortion levels of the energy quality parameters.

LED lighting for indoors can be more and cheaper in the very near future if these methods suggested in this study for energy saving, better harmonic and pf levels are used and presented for end users. Integration of LEDs and/or active filters-PWM Modules can be a significant step forward for more reliable and efficient electricity network.

ACKNOWLEDGEMENTS

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