Energy Efficient and Photometric Aspects in Renovation of Auditorium

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ABSTRACT

Lighting is a substantial energy consumer, and a major component of the service costs in many buildings. Lighting renovation was done on the Department of Electrical and Communications Engineering at the Helsinki University of Technology. The lighting in the renovated auditorium was almost 40 years old. New lamps with electronic ballast are more energy efficient and the ballast losses are smaller. Also the optical properties of the new luminiares have been greatly improved. This paper show the results obtained in one auditorium. The old luminaires with T12 lamps with old electromagnetic ballasts were replaced with new luminaires with T5 lamps and dimmable electronic ballasts. The luminaire output ratio in old luminaires was 0,39 and 0,74 in new ones.
The illuminance was more than doubled after the renovation and at the same time the power consumption was reduced 30 %.

KEYWORDS

lighting energy, renovation, energy efficient lighting

INTRODUCTION

Lighting is a large and rapidly growing source of energy demand and greenhouse gas emissions. In 2005 electricity consumed by lighting was 2 650 TWh worldwide. That means 133 petalumen-hours (Plmh) of electric light was used, an average of 20 megalumenhours/person. (IEA 2006) Global lighting electricity use is distributed approximately 28 % to the residential sector, 48 % to the service sector, 16 % to the industrial sector, and 8 % to street and other lighting. For the industrialized countries national lighting electricity use ranges from 5 % to 15 %, while in developing countries the value can be as high as 86 % of the total electricity use. (Mills 2002)

More efficient use of lighting energy would limit the rate of increase of electric power consumption, reduce the economic and social costs resulting from constructing new generating capacity, and reduce the emissions of greenhouse gases and other pollutants. At the moment fluorescent lamps dominate in office lighting. In domestic lighting the dominant light source is still the more than a century old, inefficient incandescent lamp. New aspects of desired lighting are energy savings, daylight use, individual control of light, quality of light, emissions during life cycle and total costs.

The building sector in the EU consumes over 40 % of energy use in EU and is responsible for over 40 % of its carbon dioxide emissions. Lighting is a substantial energy consumer, and a major component of the service costs in many buildings. The percentage of the electricity used for lighting in European buildings is 50 % in offices, 20-30 % in hospitals, 15 % in factories, 10-15 % in schools and 10 % in residential buildings (EU 2004). To promote the improvement of the energy performance of buildings within the community, the European Parliament has adopted the Directive 2002/91/EC on the energy performance of buildings. (Directive 2002/91/EC)

TRENDS IN ENERGY EFFICIENT LIGHTING

Electric light is obtained as a result of combination of lighting equipment. Modern lighting system needs light sources, ballasts, luminaires and controls. Part of the power input to the lighting unit is transformed into light, while the rest is considered as loss. Energy is lost in lamps, luminaires and ballasts in the form of heat. The saving of lighting energy requires the use of energy efficient components as well as the application of control, dimming, and the use of daylight.

A 35 % improvement has been presented in efficiency of T5 fluorescent lamp using mirror louvre fixture over an equivalent T8 mirror louvre fixture while using a high-frequency ballast and a standard aluminum reflector. The corresponding improvement in efficiency shown over a luminaire of the same type with conventional ballast was about 65 %. (Govén 1997).

BARRIERS FOR ENERGY EFFICIENT LIGHTING

Lighting works in a building cluster, buildings are built for 40 to 50 years. In street lighting research, it was find out that only 3 % of the installations are renovated per year and this means that it takes 30 years to change them all. The conventional electromagnetic ballast is operated at 50 Hz mains power frequency. It consists of a magnetic choke, a starter and sometimes a power factor correction capacitor. The structure of the ballast system is simple, robust and reliable. It has a very long service life.

T5-lamps are used only with electronic ballasts. Electronic ballasts have been promoted as replacements for electromagnetic ballasts for the last decade. However some costumers are still wary on the quality of electronic ballasts. Electronic ballast reduces the power losses compared to conventional electromagnetic ballast and thus reduces the energy costs. However the initial costs are higher when electronic ballasts are used. In commercial buildings it might be that the constructing or retrofitting costs are paid by ones and the operating costs by others. Then for the construction payer it is favourable to lower initial costs and that often means installation of less efficient lighting systems.

BIOLOGICAL EFFECTS

With the detection in 2002 of a novel photoreceptor cell in the eye, the effect of light on humans is better understood (Berson, Dunn, Takao, 2002). New research results have shown that light entering into human eyes has also non-visual biological effects on the human body. The quality of the luminous environment is determined not only by the light on the visual task, but also by the light entering the eye. And a good lighting quality determines not only better work performance and fewer errors, but also better safety, increased acceptance, lower absenteeism, improved health and well-being. Brainard and Glickman have published melatonin suppression curve in which the maximum is on wavelength 464 nm (2003). The melatonin suppression curve has been called also as spectral biological action curve.

According to Van Bommel awareness of the importance of the new findings is still relatively low, but is growing fast. When the biological effects are taken into consideration, the rules of the design of good and healthy design can be different from the conventional design. (Van Bommel 2005) Philips Lighting has recently launched a new lamp called MASTER TL5 ActiViva Active that has blue light content to promote well-being. The color temperature of the lamp is 17 000 K.

RENOVATION

Lighting renovation was done on the Department of Electrical and Communications Engineering at the Helsinki University of Technology. There are four major lecture auditoriums which were renovated. The building was completed in two phase on the years 1967 and 1969. The lighting in the auditorium is original, so it was almost 40 years old. This paper show the results obtained in one auditorium.

The old luminaires had T12 lamps with old electromagnetic ballasts. The nominal voltage of the ballasts was 220 V, therefore they were working on overvoltage. The nominal supply voltage is 230 V. This causes also some power losses. The dimming was done with variable voltage. There is separate cathode heating transformer that maintains full cathode heating at all time the circuit is on. Unfortunately, this means also additional power losses.

Luminaires were replaced with new T5-lamp luminaires with electronic ballasts. Since the old luminaires were almost 40 years old, also the luminaires nowadays are more energy-efficient. For instance the materials for the reflectors are improved thus improving the luminaire output ratio. Also since the light source is smaller (diameter 16 mm compared to 38 mm with T12) with proper design the lumen output is increased.

The new luminaires were Office NOVA 240TCS 2xTL5-49W, optics D6 by Idman Philips. The dimmable electronic ballast was Helvar 2x49si. The lighting control system DIGIDIM uses DALI protocol.

In addition of the “normal” lighting extra luminaires with Philips ActiViva lamps we installed. This means that lighting can be done with ordinary lamps with 4000 K or with ActiViva with 17 000 K or a mixture of these two lamps. All the luminaires are dimmable, so the colour temperature of the mixed lighting can vary between 4000 Kelvin and 17 000 Kelvin.

MEASUREMENTS

Photometric measurements were done before and after the renovation. Measured quantities were illuminance (lx) on the desks, minimum, maximum and average luminances (cd/m^2) and unified glare ratio (UGR). Illuminances were measure with LMT Pocket Lux 2 and luminances and UGR with luminance mapping system called Photolux. Photolux consists of a digital camera with fish eye lens and software. Camera is calibrated in luminance and the Photolux software integrates the calibration results and produces luminance maps out of the camera images. (Dumortier, Coutelier, Faulcon and Van Roy, 2005) Spectral power distributions were measured with Ocean Optics High Resolution Spectrometer HR 4000.

RESULTS

Figure 1 shows an example of the luminance measurements. Picture is taken after the renovation. The surface brightness of T5-lamp is higher than that of a T12 lamp. Therefore the unified glare index calculated from the lecturers point of view is higher after the renovation. UGR was 14 before the renovation and 21 after the renovation.

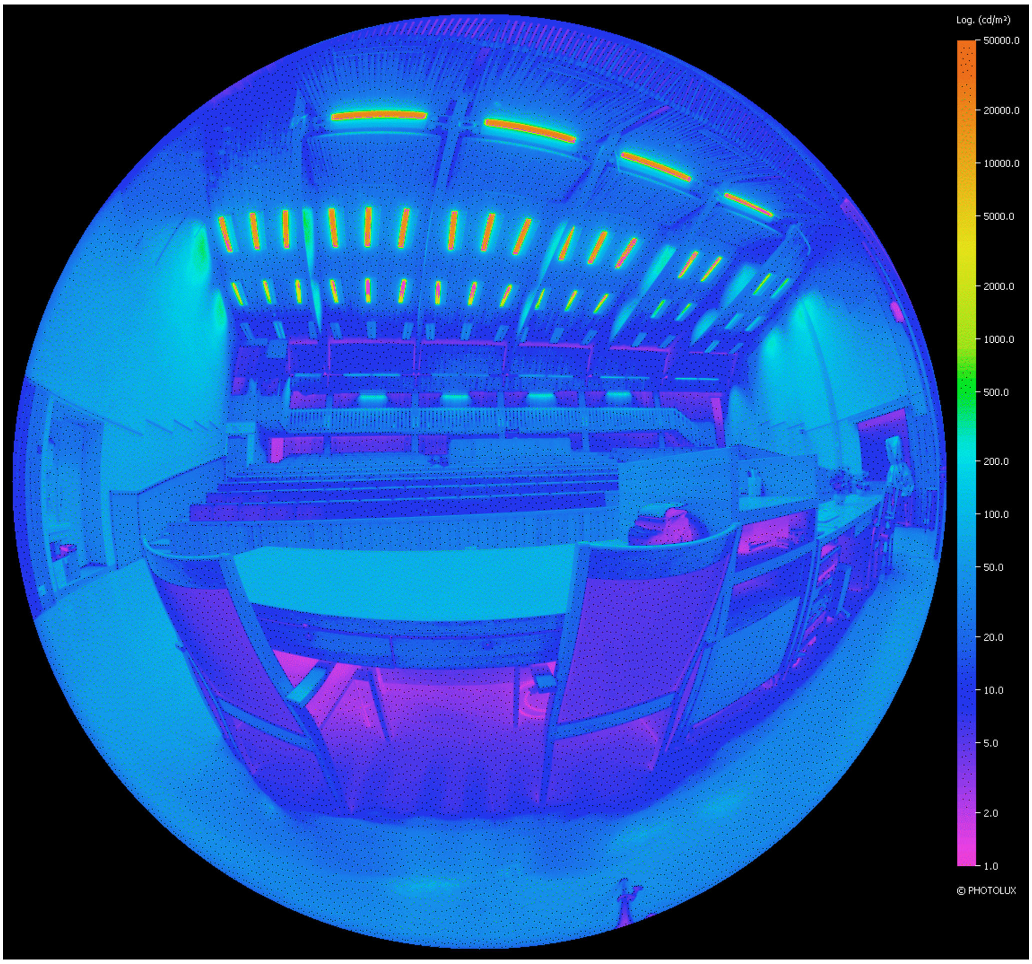

Figure 1. Luminance map of the auditorium taken after the renovation, data processed with Photolux-program.

The luminous flux of the old lamps and luminaires were measured in an integrating sphere. The CCT of the old lamps were also about 4000, but their colour rendering was weak, only about 63 (measured value). In the new lamps the colour rendering index is over 80 (81 to 83). When one luminaire with two lamps was measured with supply voltage 230 V, the total power was 121 W, with 220 V the power was 111 W. The luminous fluxes were 2142 lm and 2062 lm, respectively.

The luminaire output ratio was measured by measuring the luminous fluxes of individual lamps in an integrating sphere and then the luminous flux from the luminaire. The luminaire output ratio is then the flux from luminaire divided by the sum of the fluxes of the individual lamps, measured value was 0,39.

Figure 2 shows the spectral power distributions of the installation. The other curve is with ordinary lamps, whose correlated colour temperature is 4000 K and the other is when the ActiViva lamps are on, their CCT is about 17 000 K. The colour rendering index is over 80 in both cases.

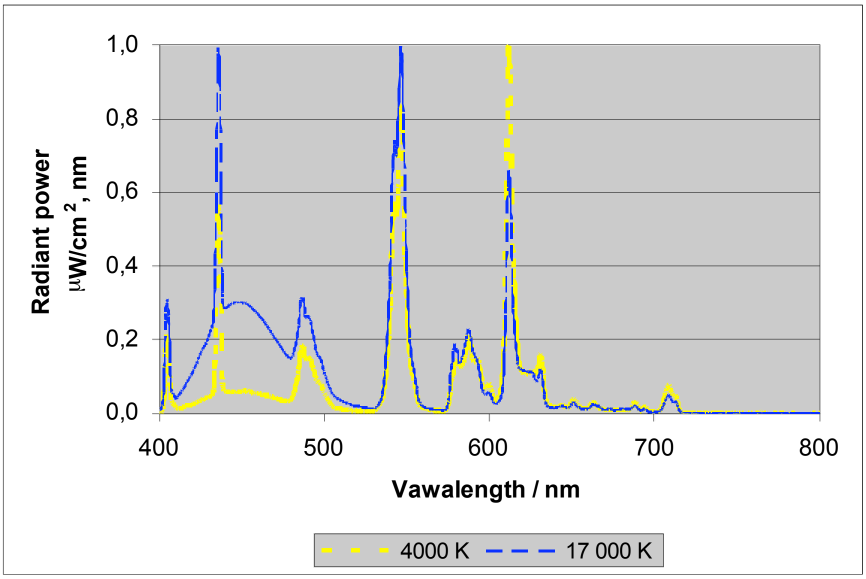

Figure 2. Spectral power distributions of the lighting measured on desk in front of the auditorium when the “normal” lights are on and when the luminaires with 17 000 K lamps are on.

TABLE 1. Photometric and electrical values of the lighting installation measured before and after the renovation.

	Before	After
Photometric values		
Illuminance lx	428	974
Average luminace cd/m^2	45	103
UGR	14	21
Electrical values		
Power(1 / W	10 571	7 383
Luminaire output ratio	0,39	0,74

(1 Power undimmed, only fluorescent lamps on the main floor area are taken into account. In the old installations there were in addition 52 incandescent lamps, 60 W each in between the fluorescent lamp luminaires. And there were also 8 incandescent lamps, 100 W each to illuminate the black board.

Table 1 shows the measured photometric and electrical values. Illuminance has been measured when lamps are undimmed. The illuminance was more than doubled after the renovation and at the same time the power consumption was reduced by 30 %. The preset value for the luminaires during ordinary lecture is that they are dimmed on average 20 %. This will increase the energy savings, but this has not been taken into account of the power consumption of Table 1.

Students´ reaction to new light sources will be studied later. It will be surveyed if the addition of short wavelengths (blue light) has an effect for instance on the alertness, mood, etc. of the students.

CONCLUSIONS

The structure of a conventional magnetic ballast system is simple and reliable. In this renovation case they had been used almost 40 years. The old luminaires used still T12 fluorescent lamps. During the years first T8 lamps come on the market and then T5 lamps. New lamps with electronic ballast are more energy efficient and the ballast losses are smaller. Also the optical properties of the old luminiares are worse than the optics of new models. The reliability of conventional ballast is a barrier to more energy efficient technology.

The renovation showed that an old auditorium can be renovated with new light sources. The result is an installation in which the quality of light has been improved and at same time energy has been saved.

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