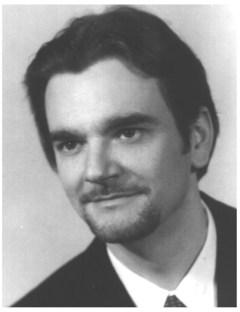
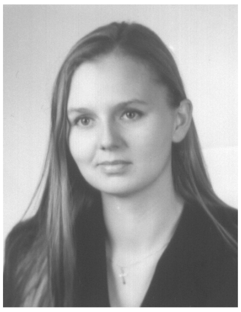
THE ENERGY EFFICIENCY OF SUPPLEMENTARY LIGHTING SYSTEMS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Summary

One of the most important aspect in design of sustainable building is them energy efficiency. In selected types of the non-residential buildings e.g. offices, people spends a majority of time during the day. Therefore, it is necessary to achieve high internal comfort parameters including lighting quality. The visual comfort is determined by required illuminance level at working plan. In the most of the office buildings required illuminance at level of 500 lx-750 lx required additional, supplementary electric lighting. Well designed daylight system lead to create the healthy and friendly environment. Non efficiency artificial light generates high energy consumption no only for lighting but for cooling as well. Therefore, in some types of the buildings well daylight system are crucial and determined the cost of maintenance, energy saving and eco-effect.

Two simulation techniques for daylight distribution have been used to estimate the electrical energy requirements. First, "**ray tracing**" method, and the second "**split flux method**". The identical cases of typical office building have been modelled in Radiance and Energy-10 at different level of accuracy. The results show the differences in energy consumption estimated by two methods and different electrical lighting systems with stepping and dimming control function. Finally, the results were tabulate for different Total Daylight Index to describe the effect of natural light in interiors illuminations.

Keywords: Illuminance, supplementary lighting, energy efficiency, daylight utilisation

1 Introduction

Nowadays, the deliberations about low-energy building design are more and more than approach based on traditional thermal aspects. The new regulations like e.g. **Energy Performance Building Directive**, also includes other forms of energy to estimate the final Building Energy Performance. The methodology of EPBD requires among others the estimation of energy for lighting in buildings. Therefore, high efficient lighting system can seriously improve final energy requirements. On the other hand, the complete lack of lighting design leads to increasing the energy consumption.

Saving energy by daylight is one of the ways to reduce electrical energy consumption. Daylight not only allowed to minimise using artificial lighting during the day but also guaranties no heating gains. Therefore, cooling energy can be considerably reduced during summer. However, for specific types of the buildings like offices, the additional artificial lighting is necessary. But the supplementary system must comply with untypical requirements. Should be independent from main artificial system, sophisticated controlled by daylight and compatible with daylighting systems, if any [1,2].

2 Supplementary lighting

Unlike traditional artificial lighting system, the proper design of supplementary lighting is always a challenge. The main difference is cross light – the daylight coming inside the room through windows or other, usually vertical openings. Additionally, the light source during the day (windows) becomes a light leakage during the night. Energy efficient artificial lighting requires sophisticated and reasonable controlled system. The main dimming scenario usually apply for supplementary light is continuous with minimum and maximum power/light fraction or stepped with total number of steps between minimum and maximum power/light fraction (**Fig. 1**) [3].

With continuous dimming, it is necessary to specify the minimum lighting level, expressed as a fraction of the peak level, and the associated fraction of energy consumption at that minimum lighting. Both defaults are zero. With stepped switching, it is necessary to define the number of steps (an integer). One step switches all the lights off when daylight meets the required level. Two steps switch half the lights off when the daylight is one-half the required level and the remaining lights off when daylight meets the required level.

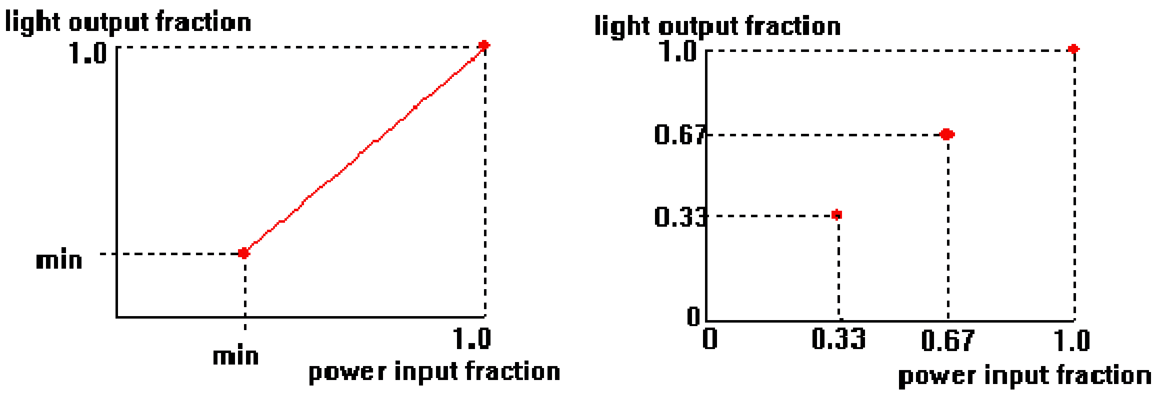

Fig. 1 Continuous and stepped (with 3 steps) dimming of supplementary light [3].

3 Problem definition

In order to analysed energy saved by daylight two methods have been used: **split flux** and **ray tracing**. The analysed cases differ in: optical properties of transparent surfaces, emissivity of interior finishing materials.

The analysed room was assumed to be occupied during the day as typical office space between 8:00 am and 4:00 pm. The required illuminance level at the working plane was assumed to be from 100 to 500 lx.

4 Results

Tab. 1 Power input for supplementary lighting with 100% efficiency at the depth of 2 m.

Required power input [W]		Distribution D [-]									
		1,0	0,9	0,8	0,7	0,6	0,5	0,4	0,3	0,2	0,1
Suplementary lighting [lx]	1000	135	150	165	165	180	195	195	195	195	210
	900	120	135	150	150	165	165	180	180	180	180
	800	105	120	135	135	150	150	150	165	165	165
	700	90	105	120	120	135	135	135	135	135	150
	600	90	90	105	105	105	120	120	120	120	120
	500	**75**	**75**	**90**	**90**	**90**	**90**	**105**	**105**	**105**	**105**
	400	60	60	60	75	75	75	75	75	90	90
	300	45	45	45	60	60	60	60	60	60	60
	200	30	30	30	45	45	45	45	45	45	45
	100	15	15	15	30	30	30	30	30	30	30

Tab. 2 Power input for supplementary lighting with 100% efficiency at the depth of 6 m.

Required power input [W]		Distribution D [-]									
		1,0	0,9	0,8	0,7	0,6	0,5	0,4	0,3	0,2	0,1
Suplementary lighting [lx]	1000	105	120	135	150	165	165	180	180	195	195
	900	90	105	120	135	150	150	165	165	180	180
	800	90	90	105	120	135	135	150	150	150	165
	700	75	90	90	105	120	120	135	135	135	135
	600	60	75	90	90	105	105	105	120	120	120
	500	**60**	**60**	**75**	**75**	**90**	**90**	**90**	**105**	**105**	**105**
	400	45	45	60	60	75	75	75	75	75	90
	300	30	45	45	45	60	60	60	60	60	60
	200	30	30	30	30	45	45	45	45	45	45
	100	15	15	15	30	30	30	30	30	30	30

Tab. 3 Energy saved by daylighting for required illuminance level at 100 and 500 lx.

Required power input [W/m^2]	Energy [kWh/a] 0÷4,5m for 100 lx		Energy [kWh/a] 4,5÷9m for 100 lx		Energy [kWh/a] 4,5÷9m for 500 lx		Energy [kWh/a] 4,5÷9m for 500 lx	
	conti.	stepped	conti.	stepped	conti.	stepped	conti.	stepped
10	658	651	466	404	571	536	114	15
50	3 290	3 256	2 328	2 018	2 853	2 678	570	76
100	6 581	6 513	4 657	4 035	5 706	5 387	1 139	152

In **Tab. 1** and **2** the required power input for supplementary lighting is presented, respectively at the depth of 2 m and 6 m. The input power was estimated for different illuminance level inside the room space (from 100 lx to 1000 lx), when dimming lighting system were assumed. The results were obtained for selected 10 values of distribution factor D. Presented results were obtained using **ray tracing** method for overcast sky model.

In **Tab. 3** the energy saved by daylight calculated with **split flux** method is presented. Two sensors were assumed: first represented the half of room space on the windows side and the second represented the second deeper part of the room. The energy was calculated with illuminance set point at level of 100 and 500 lx. Two dimming were compared – continuous and stepping (3 steps).

Presented results shows real effects of daylighting systems combined with properly controlled supplementary artificial light. In deepest part of the room (4,5-9,0 m) dimming systems seems to be up to 7^{th} time more efficient than stepping, while close to the daylight source (from 0 to 4,5 m) the differences are irrelevant.

5 Conclusions

The presented results show the scale of real possibilities in using daylight systems in non-residential buildings. The large scale effects are expected especially in offices, schools and market places. Two main factors determined the final benefits in energy consumption for lighting: solution of daylight systems and control strategy for supplementary lighting.

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