ESPr – LIGHT CONSUMPTION SIMULATION

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Abstract

This article deals with intelligent lighting which forms a specific subsystem of intelligent buildings or constructions. The aim of the experiment is to evaluate the suitability of different algorithms for lighting simulation in ESP-r tool and to compare the power consumption of “classical” and "intelligent" lighting. From these two traditional control approaches is more realistic the one, which is using a simulation of human presence and the intelligent one, which uses calibration.

Open-source program ESP-r is a sophisticated tool that is developing at the University of Strathclyde in Glasgow. It represents a simulation environment for general use which supports in-depth assessment of the factors that affect energy consumption and environmental performance of buildings.

The evaluation of simulation showed that software tools that are designed to simulate intelligent systems are very helpful in solving specific problems of various subsystems of the building. Designers can evaluate the control system already in the proposal process.

When we consider the price of 1 kWh of electricity as approximately 0.063 €, the cost savings will be only € 16 per one year. From this result can we conclude that an intelligent lighting control for smaller homes or workplaces only increase comfort of occupants or users. The real savings, which return of investments about 10-15 years can only be achieved in case of larger homes or buildings.

Keywords: ESPr, intelligent lighting, simulation of energy consumption

1 Introduction

The advantage of virtual models lies in their versatility and financial modesty. The proposed models can be easily maintained and updated by the user's own vision, without the necessity of inconvertible damage. The financial difficulty lays in their inherent SW entity, so the investments aren’t oriented into materials and technology, but to the software development, exactly to intellectual property, which increases the attractiveness of this issue in the information society.

The lighting belongs to inseparable part of the building. By appropriate manner of automation we can increase comfort and by control of daylight and artificial lighting, we can significantly contribute to energy savings of lighting. The experiments presented in this article examine the energy intensity of different lighting scenario.

2 Model for lighting simulation

The open-source program ESPr is sophisticated tool (open source), which is being developed at the University of Strathclyde in Glasgow [1]. ESPr is a simulation environment for general use, which supports in-depth assessment of the factors that affect on energy consumption and environmental performance of buildings. It is realistic and kept close to the actual physical system. It attempts to simulate real world as rigorously as possible and at a level that is consistent with current best practice.

A virtual model of a single family house was created. During the process of model creation the model’s position has to be entered and an appropriate climate database has to be attached to it. These data are important for simulating process, because the program considers the environment in calculating. The model is created by entering the coordinates of the individual walls peaks, which represent zones of different rooms.

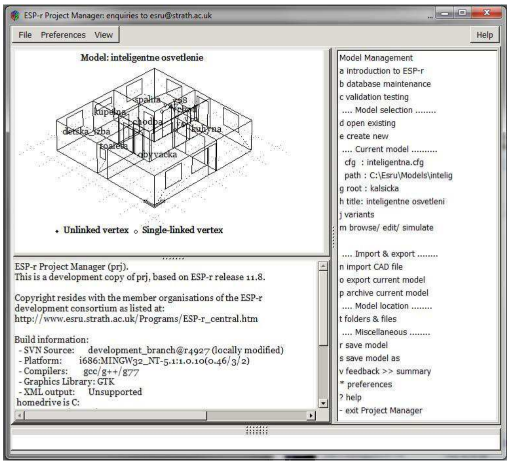

Fig. 1: Model of a simple family house (ESPr – Project manager window)

Classic Lighting

Consumption of the "classical" lighting (CL) is defined for each days and periods. Consumption is calculated according to the desired or recommended lighting in the zone (Tab.1). Control is not necessary because the periods are defined as people would turn on and off the lights. *(ESP-r simulation offers the possibility of the presence of the inhabitant, so that the simulation would be closer to reality. Both methods have been implemented for comparison.)*

Table 1: Used data (STN EN 12464-1)

	Bedroom	Bath.	Children's.	Toilet	Living room	Kitchen	Entrance	Corridor.
Area (m^2)	16.00	5.00	14.00	3.50	25.75	14.00	3.00	9.00
Luminosity (lux)	150	300	200	100	150	200	100	100
Incandescent (W) calc	170	106	198	25	273	198	21	64
Incandescent (W) real	170	110	200	40	280	200	40	80
Fluorescent (W)	33	20	38	5	53	38	4	12

The line "Incandescent (W) calc" represents calculated values and in the line "Incandescent (W) real" are the values used in the simulation. Fluorescent lamps are not used in the simulation, only in the results analysis.

Intelligent Lighting

Intelligent control (IC) sets the desired luminosity for the control. When the level of luminosity reaches the desired level (near sensors), the lights are dimmed or shut down (when daylight is sufficient). It's possible to use the data which was entered in CL. Algorithms and types of calculations have to be selected and adjusted according to user-configured rule (two versions were created). Dimming as a type of control was used in both versions. For dimming three different types of algorithms can be chosen. The first simulation uses the idealized type and the second uses the calibration type. During the dimming, when the specified limit is reached, the lights turn off. In this control it is necessary to specify the desired level of illumination (in lux - Tab. 1). The difference to the "classical" control is in the fact, that controllers have consumption. This consumption is counted as equipment consumption. It is the same during the whole day, so we don't need to specify control or periods.

3 Simulation

An important aspect is the setting of number of calculations performed per hour. In these simulations we set this number to 6.

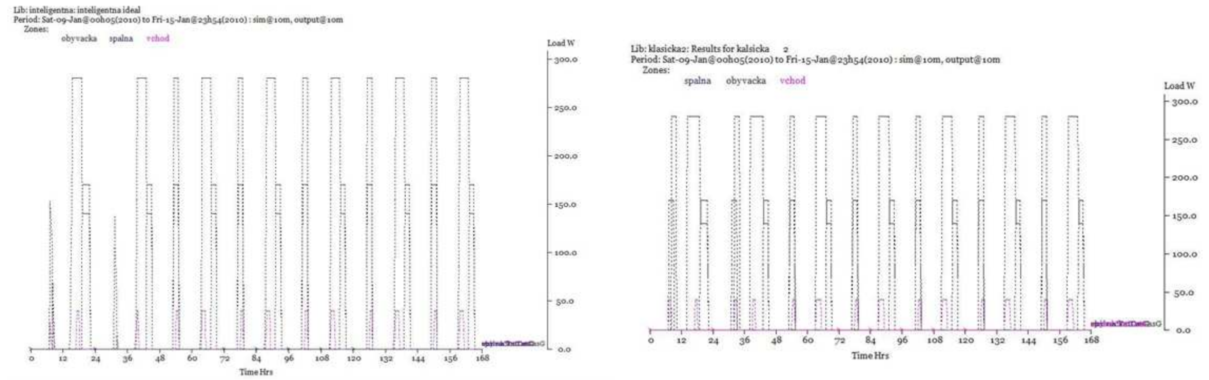

Fig. 2: Results for ideal intelligent control (left), for the classical control (right)

Simulation was done for one year for each model. It doesn't make sense to do it for longer period, due to the fact, that the climate database is defined only for one year (so for more years are data repeating). Simulations are relatively computationally intensive although this simulation doesn't represent big sophisticated system. Mentioned simulation of IC takes nearly 800 seconds (PC with 4core processor). The library size of results of IL simulation is about 330 MB and 120 MB for CL.

4 Results

Simulation results of "classical" *(Tab. 2 and Tab. 3)* represent simulation without control. *(Counts only pre-set hours for lighting).* As we expected, the highest values are reached in this simulation. These values are obtained in ideal conditions, if the lights turn on and off at the same intervals. More realistic use of "classical" lighting gives the simulation called "classical 2", which simulates user presence, which turns on and off the lights in each zone. From the tables the difference of 9.53% is obvious. It can be concluded that the simulation of CL will be better when simulation using the probability of the user, "classical 2", is used.

Table 2: Results of the simulations in kWh

kWh	Bedroom	Bathroom	Children's.	Toilet	Living ro.	Kitchen	Entrance	Corridor	Control	SUM
classical	257.05	160.59	594.34	39.64	751.86	531.76	39.64	175.22	0	2550.1
classical 2	212.96	160.35	594.34	38.74	601.41	528.46	16.77	175.22	0	2328.25
intelligent	169.18	116.4	391.78	20.42	482.48	265.36	10.09	172.89	350.25	1978.85
intelligent 2	136.41	136.41	451.32	24.59	490.01	289.65	10.22	173.87	350.25	2062.73

Table 3: Results of the simulations in hours

hour	Bedroom	Bathroom	Children's.	Toilet	Living ro.	Kitchen	Entrance	Corridor	SUM
classical	1633. 67	1581.67	3093.67	1112.67	3197.67	2780.67	1112.67	2311.67	16824
classical 2	1362.67	1579.5	3093.67	1096.17	2649.83	2766.5	482.83	2311.67	15343
intelligent	1145.5	1355.17	2571.33	753.17	2265.5	1641.67	319.5	2311.67	12364
intelligent 2	1209.17	1568.33	3016.5	971.67	2343.83	1884.67	325.17	2311.67	13631

Defined IC shows better results in the control, which uses an ideal dimming feature („intelligent“). This simulation is ideal and not real. However, it is close to the realistic (“intelligent 2”), as is shown in the difference 4.24%, which can be caused also by the fact, that the photocells in both methods are placed in two different ways[1]. The objectivity of these solutions can be appointed by comparing with data from the real house. (*Analysis of the results is carried out in ESP-r in a separate module*).

For CL, simulation “classical 2” is closer to reality and for the IC it is “intelligent 2”. Between these two approaches is 12.87% difference which is less saving than we expected. But there has been also included the consumption of intelligent control, which makes 17.7% of the total consumption. Without control the savings are about 35.96%.

Today, classical incandescent bulbs are replaced by the fluorescent lamps with the lifetime eight times higher and the consumption five times lower, so the consumption compared to incandescent lamps can be up to half. One-year consumption of the fluorescent lamps is defined as the year-round usage for the given zone (Tab.2) divided by the needed power requirement of incandescent lamps for the zone (Tab.1), and then multiplied with the necessary power of the fluorescent lamps (Tab.1). In this way we have set up Tab.4.

Table 4: Results for fluorescent lamps

	Bedroom	Bathroom	Children’s.	Toilet	Living ro.	Kitchen	Entrance	Corridor	Control	Bedroom
clas. 2 – incand.	212.96	160.35	594.34	38.74	601.41	528.46	16.77	175.22	0	2328.25
clas. 2 – fluor.	41.00	29.82	113.46	4.62	113.13	100.89	1.72	26.88	0	431.52
intel. 2 – incand.	136.41	136.41	451.32	24.59	490.01	289.65	10.22	173.87	350.25	2062.73
intel. 2 – fluor.	26.26	25.37	86.16	2.93	92.18	55.30	1.05	26.67	350.25	666.16

It is obvious that savings with fluorescent lamps compared to the conventional bulbs exceed five times multiple. Another obvious fact is that IC consumption is higher than in the classical (for fluorescent lamps). We can conclude that for the fluorescent lamps it is better to use CL than to use IC due to the low savings and high price of IC solution *(in small and medium-sized family homes)*. The difference is 54% percent, but the consumption is only 4-600kWh *(54% means around 200kWh)*. The savings of lighting without control are about 115 kWh, so when the house area is three times greater, than the consumption for controls is balanced. It means that the consumption will be the same, but the initial cost of IC remains still bigger in comparison with CL.

[1] While for the ideal sensors are placed one meter from the ground and face up, the second method, which uses the calibration (Integral reset) are oriented at the ceiling and facing down. Light sensors in these simulations are placed differently because they use different algorithms and they require different location.

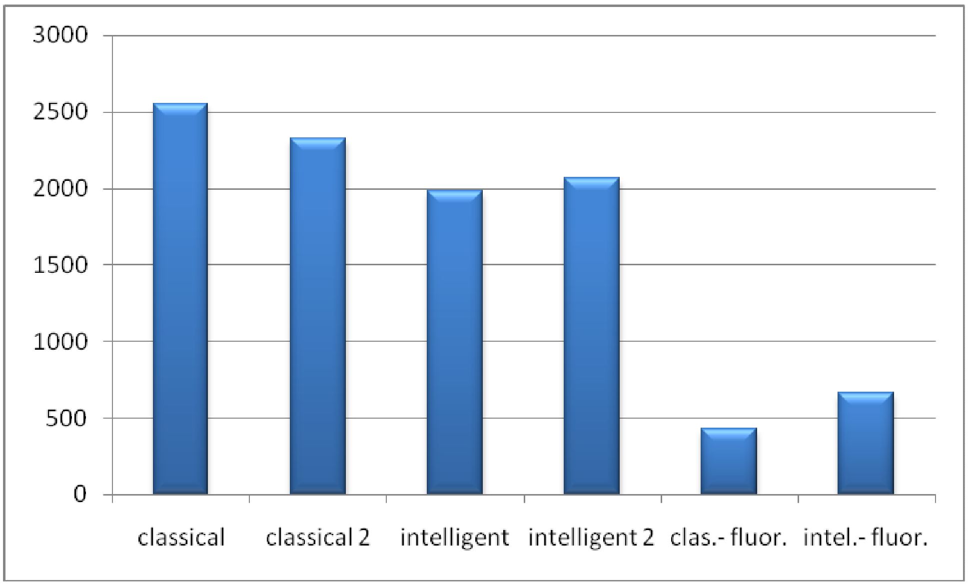

Fig.3: Liftime consumption in kWh

5 Conclusion

The model simulations creation and evaluation shows that the software tools, which are designed to simulate intelligent systems are very helpful in solving many various problems in area of intelligent building or building in general. By this manner designers can assess the systems of control already in their design phase.

In consideration of the price per 1 kWh of electricity (0.063€), the achieved savings for the entire year for the selected house are only about 16 €. From this we can conclude that the intelligent lighting control for smaller homes or workplaces affords just higher comfort for users or inhabitants. The real savings, which give payoff around 10 to 15 years can be only achieved with larger houses or buildings. For two times bigger house (as we counted), the consumption of electricity will be two times higher (4650kWh - LTC) for classical lighting. The power consumption of intelligent lighting will be also increased around twice, with the fact that consumption of control will increase only slightly, so consumption will be about 3430kWh for lighting and 400kWh for control (together 3830kWh). This represents a saving about 21.4%, which means that the savings are almost linearly proportional. For larger houses (> 300 square meters) it could be possible to reach the savings up to about 33% (2310kWh - LTC). Considering the price of the solution the payoff time is in the range of 15-20 years.

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