DOCTORAL SCHOOL IN ENVIRONMENTAL ENGINEERING

Michela Chiogna

Energy efficiency and saving on lighting systems in existing buildings: intervention strategies

ABSTRACT

Supervisor: Antonio Frattari

Given new and emerging standards and requirements in Europe regarding energy performance of buildings (see, for example, EPBD 2002/91), it has become increasingly important to improve the energy effectiveness of building operation. Toward this end, efficient daylight-responsive systems for illumination of buildings (including installation of automatic lighting control systems) can provide a significant contribution (EN 15193).

This research aims to define a new methodology for the design of lighting systems in the lecture halls. The experimental phase, focused on a specific case study, is based on the comparison between the energy consumption for the lighting control in the actual situation without control system and a designed one with an automation system.

A completed analysis of the state of the art about sustainability and voluntary protocols, innovation in field of energy saving, lighting automation systems, visual comfort, illumination and vision has been developed.

The case study analyzed is the Faculty of Engineering of Trento. The cross layout of this building is characterized by two parallel wings, both with the same south exposure. The lecture halls are symmetrical and have the same shape. This configuration allows the simultaneous comparison. The research's method has been divided in four phases:

1- <u>Analytical phase: monitoring and analysis of existing situation</u>

This phase deals with measure of the average luminance on the work desk, assessment of the luminance uniformity and glare control (UNI EN 12464-2/2004).

2- <u>Programmatic phase: definition of project objectives and system requirements</u>

This phase focus on the configuration of Scenarios to switch on/off the lighting system in relation with the lecture hall use, the natural light contribution, the maintenance state and the efficiency of the lights; definition of requirement for a supervision system, monitoring and implementation of a data bank for the photometric data and for the energy consumption .

3- <u>Propositional phase: system solution</u>

In this step the preparation of drawing boards and technical reports for the adopted solutions, for both the activation typology and modality of activation of the automatic control system for the position and technical characteristics of the devices installed and integrated in the automation system have been developed. In order to pursue the reduction of energy demand and the visual comfort improvement, the following factors have been considered:

1. control of the students presence with in the lecture room, as a necessary condition to turn on the light
2. regulation of the constant light, in relation to the window distance

3. a partial switching off of the lecture room, if only half space is occupied
4. introduction of a new kind of high efficiency light

For the evaluation of these aspects the monitoring of the following data has been carried out:

- Counting the dimming percentage for each light line in the three rooms. In this way the evaluation of the function modality for the system and for the partial energy consumption will be more efficient.
- Monitoring the presence of student in the lecture rooms, both the ones with intelligent devices and the traditional ones, in order to make a scientific analysis of the energy consumption, normalized through the real occupation time of the two different wings.
- Verify when and how many times the automatic regulation is forced by the manual regulation, in order to evaluate the visual comfort for the users in a building automation system.
- Measuring and registering the illuminance level in the lecture rooms with and without intelligent devices, in order to evaluate the natural light use for the visual comfort. This evaluation is not necessary for the lecture rooms with the constant light automation system that is intrinsically designed to maintain the programmed luminance.

4- <u>Evaluation phase: evaluation and verification</u>

The main goal of the evaluation phase has been to individuate and quantify the differences between the calculated model and the real behaviour of a monitored building.

The developed methodology focuses on the following issues:

1. simulation, calculation and discussion of the Adeline software tool outputs, in collaboration with the Fraunhofer Insitute of Stuttgard (Eng. J. de Boer), and comparison with the monitored data;
2. elaboration and statistical analysis of the users behaviour, calculated with the Technical University of Wien (Prof. A. Mahdavi), in order to introduce improvements in the modelling process;
3. evaluation of the visual comfort maintained and perceived by the users, in relation with the illumination levels standard, in order to verify if the proposed model allows the visual comfort users requirements, in collaboration with the Ophthalmology ward of S.Chiara hospital in Trento (Prof. De Concini).

1. The comparison between Adeline outputs and data monitored focus on the following issues: calculate the difference between the inside illuminance conditions for the simulation model and for the real class rooms; calculate the outside conditions for the model (in particular the sunshine probability) and to verify the variance of statistical sky conditions; understand and quantify how much the recorded users behaviour differs in lecture halls, compared with that one used in the simulation tool; analyze how the automated systems work in a real situation and how much energy saving has been expected looking for the Superlink output.

2. The energy saving potential for each scenario has been calculated related to a reference energy demand level, named ML (maximum level), that corresponds to the traditional classrooms. In order to understand and model users' behaviour in ML and to quantify the energy saving potentials of automation systems for lighting control, a typical day data analysis has been carried out. In this way it is possible to perform an hourly data analysis, depicting typical patterns of presence, actions, and energy use over time instead of mere daily overview. Monitoring results are stored in a databank and structured by the supervision software Gefasoft 7.1. For each day, a file is generated with temporally ordered data. Each single message is labelled with a distinctive number by means of a specific FORTRAN program. The different data points

have been synchronized using a specific LabView program. The lighting energy use in the lecture rooms for the implemented scenarios has been compared using standardisation techniques. In particular the following normalisation factors have been considered: occupancy level, outside illuminance, indoor illuminance factor.

3. In order to analyze the visual comfort, a significant student sample has been tested. The goals of the subjective analysis are: check, if present, the uncorrected refractive errors of the students, for different contrast conditions; define the critical detail for the student in a typical lesson condition, for defined boundary conditions; compare the veiling luminance level perceived and the literature discomfort value; to evaluate the visual discomfort indexes of the students; analyse the visibility, as calculated and perceived value, for defined boundary conditions.