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IMPLEMENTATION OF FUZZY LOGIC IN THE MANAGEMENT OF ARTIFICIAL LIGHTING SYSTEMS

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ABSTRACT
The use of daylighting represents a main goal for building operators in order to implement a suitable energy management. Unfortunately, daylight is a dynamic source of lighting and classic control systems present difficulties to adjust their performances to these rapid changes. As a result fuzzy control could be a better solution. The paper analyzes the possibility to implement this new technique in daylighting control and presents the structure of a fuzzy controller proposed by authors.
Keywords: energy management, lighting systems, fuzzy logic

1. INTRODUCTION
Nowadays 30% to 45% of a building's electricity bill is typically for lighting so that this sector is considered as having an important potential regarding energy savings. The lighting controls play a key role in this action, providing building operators with the means to manage the way lighting energy is used more efficiently. According to [1], lighting controls can reduce lighting energy consumption by 50% in existing buildings and by at least 35% in new construction.
The sustainable development concept has revived the interest for daylighting, i.e. for the use of daylight as a primary source of illumination in a space as any day lit area has very promising energy-saving opportunities. Unfortunately, daylight is a dynamic source of lighting, i.e. the illuminance from the sky is not constant, and the variations in daylight can be quite large depending on season, location or latitude, and cloudiness.
Classic control systems present some difficulties to adjust their performances to the rapid changes in daylight and to occupants’ preferences. Taking into account these aspects, fuzzy control could be a better solution. The paper analyzes the possibility to implement this new technique in daylighting control and presents the structure of a fuzzy controller proposed by authors; its operation rules and the influence on the imposed value of the illuminance level are also studied.

2. LIGHTING CONTROLS
Lighting controls, addressing controls for electric lighting, offer desired illuminance at appropriate times while reducing energy use and operating costs of lighting system. In fact, all of them aim one of the two following goals: energy management and esthetics. Energy-management controls provide energy saving through reduced illuminance or reduced time of use; esthetic controls provide the ability to change space functions and create emotional appeal, i.e. to adjust the lighting to suit the purpose, to maintain human visual performance and to change the mood of the space.
All lighting control systems are based on one of the following strategies:
- *Occupancy sensing,* in which lights are turned on and off or dimmed according to occupancy;
- *Scheduling,* in which lights are turned off according to a schedule;
- *Tuning,* in which power to electric lights is reduced to meet current user needs;
- *Daylight harvesting (daylighting control),* in which electric lights are dimmed or turned off in response to the presence of daylight;

- *Demand response,* in which power to electric lights is reduced in response to utility curtailment signals or to reduce peak power charges at a facility;
- *Adaptive compensation,* in which light levels are lowered at night to take advantage of the fact that people need and prefer less light at night than they do during the day.

These strategies can be accomplished by means of various control devices, but any lighting control system contains three major components: (1) a power controller, (2) a logic circuit and (3) a sensing device. The *sensing device* is capable to measure or to detect a physical parameter of interest (e.g., illuminance level) and to translate it into an electric signal (current or voltage); the *logic circuit* accepts this electric signal and, using a specific algorithm, converts it into an appropriate electric signal for the power controller; the *power controller* acts on artificial lighting source in order to obtain the proposed goal. These systems can be quite sophisticated, and the equipment used to achieve the required control functions varies in complexity from simple timers to intricate electronic dimming circuits. Each of these technologies can be applied individually with much benefit, but by creatively combining them, designers can deliver even greater value to their clients.

The sustainable development concept has revived the interest for daylighting, i.e. for the use of daylight as a primary source of illumination in a space; except for energy savings, daylighting provides an improved sense of well being. According as more buildings are designed for sustainability, demand for daylighting controls continues to increase because lighting controls offer interesting energy-saving opportunities to any daylit space. Primary factors include the amount of daylight available and the occupancy pattern, plus the control strategy; in addition, since ample daylight is often available during utility peak demand hours, daylight harvesting can reduce demand charges, particularly valuable if a “ratchet clause” is in effect. Although the use of the daylight can offer substantial cost savings, the benefits to the occupants from exposure to healthy sunlight are also significant.

There are at least two dimensions to daylight-responsive controls [2]: the control of the daylight input to the space, and the control of the electric lighting output. The first is critical for providing adequate quantity and quality of daylight in interior spaces; the second saves energy and improves the overall distribution of light when daylight is insufficient.

Fluorescent lighting is the light source generally used with electric lighting controls and fluorescent lamps with a colour temperature within 3,000-4,500K are most likely to be in agreement with the colour temperature of daylight. When both daylight and electric light are used, care should be taken to minimise luminance differences between the window area and its surroundings to ensure visual comfort. Interior surfaces need to be light in colour to maximize the inter-reflection of light. In addition, particular care should be taken because of specular reflection that results from the shiny or mirrored surfaces that are sometimes used as components of the daylighting system and/or shading device.

The daylighting control is based on continuous dimming techniques that allow users to adjust lighting levels over a wide range of lighting output and offer far more flexibility than step-dimming controls. As continuous dimming follows the daylight pattern very closely, it is often more acceptable to occupants, and can produce higher energy savings, particularly in areas with highly variable cloud cover. Continuous dimming also responds to changes in light output due to dirt depreciation on fixtures and lamps, and lamp lumen depreciation due to lamp aging.

Continuous dimming is achievable using either analog or digital ballasts. Analog is the standard dimming method, typically presents a lower cost, and is compatible with a wide range of common control devices. The controller varies the control signal sent to the electronic ballast in order to maintain the desired level. With standard 0 – 10V DC dimming ballasts, 10 volts signal the ballast to provide full light output. 0 volts signal the ballast to provide minimum light output.

3. FUZZY LOGIC AND DAYLIGHTING CONTROL

Daylight is a dynamic source of lighting, i.e. the illuminance from the sky is not constant, and the variations in daylight can be quite large depending on season, location or latitude, and cloudiness. In consequence, any prediction system has to be flexible to allow for the multivariate changes that characterize the combination of sunlight and skylight. In recent years, the control technology has been well developed and has become one of the most successful tools in the industry. However, due to above mentioned aspects, traditional control systems, based on mathematical models, and often

implemented as “proportional-integral-derivative (PID)” controllers, have shown their limits as daylighting energy-management controls. Taking into account the random pattern of potentially available daylight and rapid change of its characteristics, fuzzy control has proved to be a more convenient solution.
Fuzzy controllers are very simple conceptually. They consist of an input stage, a processing stage, and an output stage. The input stage maps sensors or other inputs, such as switches, thumbwheels, and so on, to the appropriate memberships functions and truth values. The processing stage invokes each appropriate rule and generates a result for each, then combines the results of the rules. Finally, the output stage converts the combined result back into a specific control output value.
The internal structure of a fuzzy controller is presented in Fig. 1 and contains four basic components [3]: *Fuzzification unit*, *Knowledge base*, *Inference unit*, and *Defuzzification unit*. The daylighting fuzzy control uses a fuzzy controller as the logic circuit of the lighting control and continuously electronic dimming ballasts controlled by low-voltage analog signals as power controllers. The ballast receives a signal from the control device and subsequently changes the current flowing through the lamp, thereby achieving a gradual controlled reduction in lamp output. The characteristics of the control signal affect the duration and extent of the change in current and subsequent lamp output. As the sensing device, different types of photo-sensitive devices, commercially available, can be implemented.
For the studied room (20x10 m), the indoor pendant-mounted lighting system, designed by DIALUX software package [4], consist of 30 luminaires containing two 54WT16 linear fluorescent lamps. They are mounted in five rows and six column, parallel to the dayligth side of the room, and assure an average illuminance level of 500 lx. An important task consists in the proper selection of control zones; a control zone is a group of luminaires or individual lamps within luminaires that are controlled by one signal. In the studied case, the pattern of the daylight is presented in Fig. 2; accordingly, three control zones have been identified.

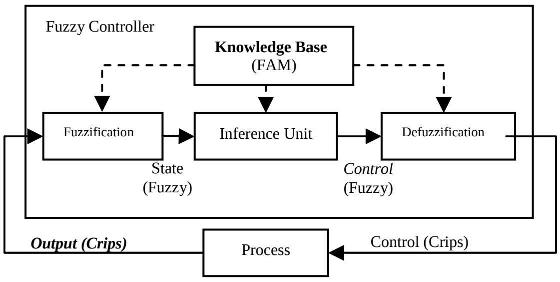

Figure 1. Basic structure of fuzzy logic controller

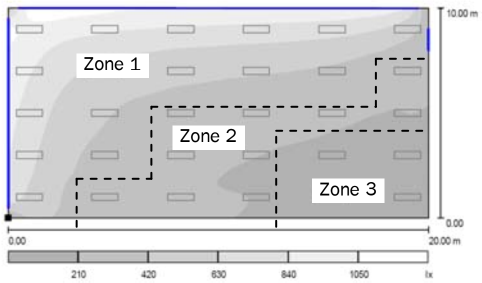

Figure 2. Daylighting of the room

4. PROPOSED CONTROL SYSTEM

The proposed daylighting fuzzy control uses four sensing devices (an occupancy/motion sensor and three photosensors), continuously electronic dimming ballasts for every luminaries aiming the control of the electric lighting output, and a fuzzy controller; the three photosensors are placed in the control zones 1, 2 and 3.
The input linguistic variables of the fuzzy controller are the level of the illuminance measured by the three photosensors while the output variables are the level of the DC control signal sent to electronic ballasts in the three control zones. Every linguistic variable has five fuzzy values with triangular or trapezoid membership functions, as follows:

- For input variables – Figure 3: *D* – dark; *HD* – half dark; *H* – half; *HL* – half light; *L* – light;
- For output variables – Figure 4: *VL* – very low; *L* – low; *M* – medium; *H* – high; *VH* – very high.

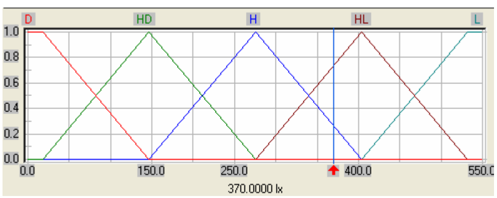

Figure 3. Input variables fuzzyfication

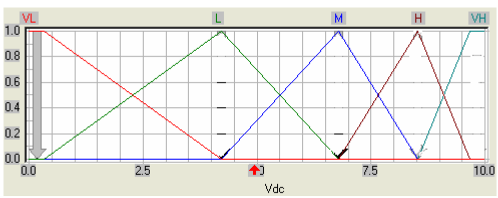

Figure 4. Output variables fuzzyfication

The knowledge base used by the control system is presented in Table 1 where μ_i (i=1…4) represents the membership functions for the DC control signals corresponding to the four control zones.

Table 1

IF			Then		
A	**B**	**C**	μ_1	μ_2	μ_3
D	D	D	V_H	V_H	V_H
D	D	HD	V_H	V_H	V_H
D	D	M	V_H	V_H	V_H
...	...	...	...	...	....
L	L	L	V_L	V_H	V_L

The processing stage invokes each appropriate rule and generates a result for each of them, then combines the results of the rules; this mechanism was implemented by the *max-min* inference method. The results of all rules that have fired are defuzzified to a crisp value by the *centroid* method and gives different crisp values of DC control signals corresponding to each control zone. Simulated results have been obtained by FuzzyTech tool [5].
The illuminance levels provided by the proposed fuzzy control system are presented in Figure 5 and highlight a good quality of illumination combined with a significant energy saving.

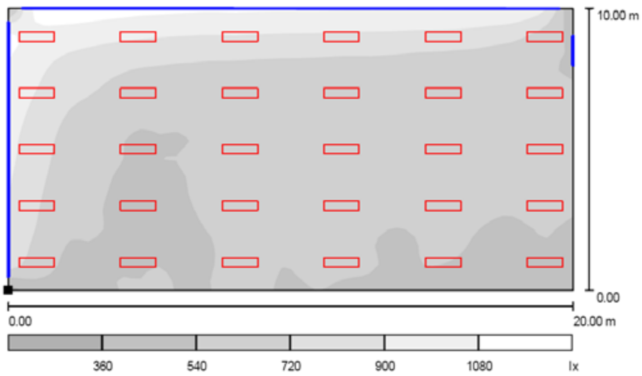

Figure 5. Combined artificial and daylighting with fuzzy controller

5. CONCLUSIONS

Daylighting has a very promising energy-saving potential and became an attractive alternative to conventional indoor electric lighting systems. Classic control systems, based on continuous dimming, present some difficulties to adjust their performances to the rapid changes in daylight depending on season, location or latitude, and cloudiness.
Taking into account these aspects, fuzzy control could be a better solution in implementation of daylighting, an issue that cannot be easily represented by mathematical modelling because data is unavailable, incomplete, or too complex.
The proposed system uses four sensing devices (an occupancy/motion sensor and three photo sensors), continuously electronic dimming ballasts for every luminaries aiming the control of the electric lighting output, and a fuzzy controller. Data obtained by simulation proved the correctness of the proposed solution.

6. REFERENCES

[1] ***, IEEE Recommended Practice for Electric Power Systems in Commercial Buildings, IEEE Std 241-1990
[2] Daylighting Control. Design and Application Guide DAYAPPS_1206 Legrand
[3] M. Chindris and A.Cziker, Application of fuzzy logic in power systems. MEDIAMIRA, Cluj-Napoca, 2004.
[4] http://www.dialux.com/
[5] http://www.fuzzytech.com/index.htm