SUPPORT FOR ENERGY AND COMFORT MANAGEMENT IN AN OFFICE BUILDING USING SMART ELECTROCHROMIC GLAZING: DYNAMIC SIMULATIONS

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ABSTRACT

In this research, we look for a control strategy of the electrochromic windows, depending on the measurement of the vertical outdoor illuminance and the outdoor temperature, for an efficient highly glazed office building in Brussels. We simulate this building in TRNSYS. We implement a Perez model in TRNSYS to assess the vertical diffuse outdoor illuminance. As the building is equipped with a dimmable lighting system, we assess the average indoor illuminance. We simulate the switching dynamics of the electrochromic window and we implement a control strategy. Finally, we evaluate the primary energy consumption due to HVAC and lighting, the risk of overheating and the average indoor illuminance.

INTRODUCTION

Active windows take part in the management of visual comfort and overheating as well as cooling and heating demands and lighting consumption. Their interest is particularly increased in highly glazed office buildings. *"Switchable windows give vision to the outside and help save energy"* (Hulsey, 2010). Hulsey performed simulations using TRNSYS. She showed that an electochromic glazing could help to eliminate much of the overheating. Zinzi (Zinzi, 2006) conducted a survey with 30 people who agreed to be submitted to a questionnaire for tests held in an office representative cell with two electrochromic windows: the first one in the north behind the occupant and the second one in the west facade to the right of the occupant. In short, the occupants told that the electrochromic glazing provided a uniform level of daylight in the room if there was no beam irradiation and if the sky illuminance was not high. The period of the switch did not satisfy several occupants. They liked the possibility of manually controlling the windows and they enjoyed less the automatic mode. The Lawrence Berkeley National Laboratory also conducted a survey (Clear et al., 2006) to test an electrochromic window placed on the south facade of a test cell equipped with a venetian blind. The lighting is a dimming control system. The occupant sat to the east. The study compared three operating modes of the glazing system and assessed the resulting indoor comfort: an automatic mode, a semi-automatic mode and a manual-mode. The occupant had the opportunity to use the venetian blind. 43 subjects participated to the tests and to the questionnaire. The experiments were performed in winter and mid-season. There was no discomfort due to overheating. The second conclusion from this study is the appreciation of the subjects for using three operating modes. Automatic and semi-automatic modes for which the transmission of the glazing varies were more appreciated than the reference glazing in which the transmission is fixed. In general, subjects like the electrochromic glazing, but most of them would have preferred that the glazing transmission could get lower (in this case the minimum level was 6%). 95% of the subjects were affected by glare during the tests. The most common source was the window (59%) and reflections on the computer screen or walls. Occupants highly appreciated the continuous view to the outside offered by the electrochromic window. The blind was used by 1/3 of the occupants mainly to eliminate glare phenomena. The same Berkeley laboratory had conducted a complete study (Lee et al., 2006) on the electrochromic glazing to give designers precise information about the performance of electrochromic windows. They applied a control strategy based on an algorithm that searches for a compromise between visual comfort and energy efficiency. The electrochromic glazing was compared to a low-emissivity glazing. It would reduce peak cooling demand by 19 to 26%. The report also shows that for cold climates such as the German climate, the most appropriate control strategy is that the glazing is dark during the summer and clear during the winter. This strategy was used to test three electrochromic glazings in the project conducted by the group "Performance Solar Building Façade Component" of the International Energy Agency IEA 27 (Subtask A). The windows are dark when the need is for cooling, they are clear when the need is for heating (Köhl et al., 2006). This strategy was chosen because of its simplicity although the working group admits that the problem is multi-criteria. Simulations were conducted for 3 European climates: Rome, Brussels and Stockholm. The important conclusion of this report is that the cooling power is considerably reduced. Other studies dealt with control strategy of electrochromic glazing. Assimakopoulos (Assimakopoulos et al., 2004), compared, using simulations, few windows in terms of energy use: a simple 4mm clear glass (base case), a clear double-glazing with a low-emissivity coating, a double-glazing with a low emissivity and reflective coating, the clear mode of the electrochromic glazing, the dark mode of the electrochromic glazing and the same electrochromic glazing used in clear mode during winter and dark mode during summer. The latter strategy seems to be the best one. It would reduce the heating and cooling demands by 38.8% and 65.2% respectively compared to the base case for the Athens climate.

The aim of the project related in this paper is to design an autonomous system: the control strategy is exclusively based on the data of the sensors that are integrated in the glazing system. It is not possible to place sensors on the outside because they have to be located on the electronic board. Figure 1 describes the electrochromic glazing system. It consists of two tempered glasses the thickness of which is 4mm and an electrochromic layer located on the outer side of the glazing system. The inner tempered glass has a low emissivity coating on its outside part. The gap between the electrochromic layer and the inner glazing is filled with argon gas. The transition from the clear state to the dark one and vice-versa requires a voltage of 2V and a current of 68mA. This power is supplied by a photovoltaic cell located between the electrochromic layer and the outer tempered glass. The electronic board on which are placed the sensors is placed on the PV cell. A battery can store excess power and release it when there is no solar irradiation.

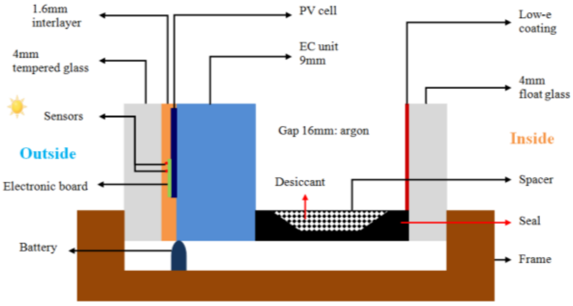

Figure 1 The electrochromic glazing equipped with sensors for the control

We highlighted through the literature review the relevance of a glazing control strategy that gives priority to eliminate overheating in summer and another one that gives priority to visual comfort in winter. TRNSYS is a dynamic simulation software dealing with heat transfers but it is not designed a priori to address problems of visual comfort. However, the weather files used by TRNSYS provide the global horizontal illuminance measured in the absence of obstruction and TRNSYS computes diffuse horizontal illuminance. So this weather data will be used to assess the illuminance within an office and visual comfort.

In the first part of the simulation work, the building model in TRNSYS is described. We especially explain the modelling of electrochromic windows and the switching dynamics. The second part of the simulation work is devoted to processing visual comfort in TRNSYS. Thirdly, we expose the algorithm for the management of visual comfort, thermal comfort and energy. After exposing the simulation work, we present the results and discuss them.

SIMULATION

The office building model

The modelled building is a ten story office building existing in Charleroi (Belgium) whose external glazing area represents 90% of the external façade area including the glazing. The building is modelled for the climate of Brussels. We modelled an intermediate floor. Because of the significance of the glass surface, the simulation is performed by using TRNSYS 3d coupled to the Type 56 of TRNSYS. TRNSYS 3d uses the Gebhart coefficients method. Thus the solar irradiation distribution inside the room is calculated with better accuracy. The main geometrical features and the zoning design of the building are summarized in Table 1. The figure 2 is a SketchUp representation of an intermediate floor of the building. Each floor consists of one core zone surrounded by five perimeter zones. These perimeter zones are considered as office rooms while the core zone (zone 1) is a circulation zone. Each thermal zone is conditioned except the circulation zone. The floor to ceiling height is 2.8m while the floor to floor height is 3.0m.

Table 1
Geometry data and thermal zoning

Zone	**Area (m^2)**	**Volume (m^3)**	**Glass area (m^2)**
4	189	529	79.4
Meeting	56	157	16.6
5	51	142	33.4
2	133.2	373	40.5
3	177	496	43.0
1	168	470	0

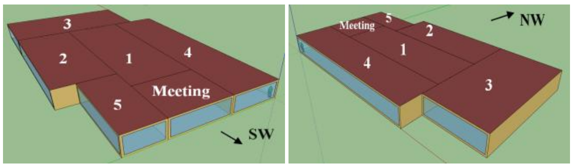

Figure 2 A SketchUp representation of an intermediate floor. For the simulation, the meeting zone is considered as an office room.

The external walls are composed of an inner layer of gypsum, a layer of normal concrete, a layer of mineral wall and another layer of normal concrete. The U-value is 0.308W/m^{2}K.

The electrochromic glazing can take five different states: a dark one, a clear one, and 3 intermediate states. Table 2 shows the values of the main thermal and optical coefficients of the electrochromic glazing and the reference glazing to which is compared the electrochromic glazing. We composed the electrochromic glazing using WINDOW6, software developed by the LBNL (Lawrence Berkeley National Laboratory). Each state of the electrochromic glazing is defined in WINDOW6 as a full glazing system. To do this, we select the frame type from an existing library, then the thickness of each layer of the glazing system, the coefficients of transmittance and reflectance in the full solar spectrum and in the visible one, the transmittance and the emissivity in the infrared spectrum and the conductivity of each layer of glass. After defining each layer of glass, we define the complete glazing system consisting of layers of glass, a gas filling the spacer, and their layout. Then the software calculates the solar heat gain coefficient, the U-value and the optical quantities for different incidence angles. The data are stored in a DOE2 file which format is the same as these of TRNBUILD. Therefore the file is directly used by the Type 56 of TRNSYS. At this stage we defined five windows corresponding to the states of the electrochromic glazing. In Type56 each glazing is recognized by an identifiant number (ID number). So, in the DOE2 file we attribute ID numbers to the glazings composed in WINDOW6. Finally we can control the state of the electrochromic glazing by simply involving the ID numbers in equations. We introduce in TRNSYS the variables Switch2, Switch4, SwitchMeeting that can take the values [0; 1; 2; 3; 4] depending on the state of the electrochromic glazing. Thus we can define the ID numbers according to the variable Switch.

$$ID = Switch + 7001 \tag{1}$$

In TRNSYS, we look for a degree 4 polynomial that expresses the visible transmittance of the glazing according to the Switch variable:

$$T_v = \alpha_0 + \alpha_1\,Switch + \alpha_2\,Switch^2 + \alpha_3\,Switch^3 + \alpha_4\,Switch^4 \tag{2}$$

This amounts to solve a linear system of five equations and 5 unknowns that are the coefficients of the polynomial. We find:

$$T_v = 0.463 - (119/500)\,Switch - (31/6000)\,Switch^2 + (41/6000)\,Switch^3 - (1/750)\,Switch^4 \tag{3}$$

This reasoning assumes that the visible transmittance is constant for each state of the glazing and independent of the incidence angle of solar radiation, which is true between 0 and 65°, but no longer between 65 and 90°. We could refine the control by setting the conditions of the incidence angle. In our case, the transmittance of the glass will be slightly increased. The variable “Switch” is defined by the control algorithm presented in the third section. It depends on the season, the vertical illuminance on the glass facade, the room occupancy and the glazing state. Table 3 shows the variables used by the control algorithm. It also shows the correspondence with ID numbers. We assume that the switching dynamics is linear. The switching from a state to the next one is done in four minutes. The delayed output device, modeled by the type 661 of the TESS library, maintains inputs for a time expressed in numbers of time steps before providing outputs. **The time step of the simulation is 2 minutes** and the Type 661 maintains inputs for 2 time steps. If the conditions are met for the glazing to evolve to the dark state then the algorithm orders the glazing to move from state i to state i+1 and the variable $switch_i$ becomes $switch_{i+1}$. $Switch_{i+1}$ is used in equation (3). The new calculated transmittance Tv_{i+1} is processed by the algorithm with a four minutes delay. A similar approach is used for the passage to the clear state or for maintaining the same state. The diagrams in figure 3 describe how the switching dynamics is integrated to the control strategy.

Table 2

Main thermal and optical coefficients of the electrochromic glazing and the reference glazing

Glazing	Light transmittance	Solar transmittance	Reflectance	SHGC	U-value (W/m^{2}K)
Electrochromic					
Clear	0.463	0.230	0.197	0.315	1.25
Intermediate 1	0.384	0.176	0.137	0.263	1.26
Intermediate 2	0.317	0.140	0.108	0.227	1.26
Intermediate 3	0.255	0.109	0.089	0.196	1.27
Dark	0.150	0.064	0.071	0.150	1.27
Reference	0.786	0.596	0.112	0.709	1.26

Table 3
Variables used by the control algorithm and correspondence with ID numbers

Glazing state	Visible transmittance	Switch	ID number
Clear	$Tv_0=0.463$	$Switch_0=0$	7001
Intermediate 1	$Tv_1=0.384$	$Switch_1=1$	7002
Intermediate 2	$Tv_2=0.317$	$Switch_2=2$	7003
Intermediate 3	$Tv_3=0.255$	$Switch_3=3$	7004
Dark	$Tv_4=0.159$	$Switch_4=4$	7005

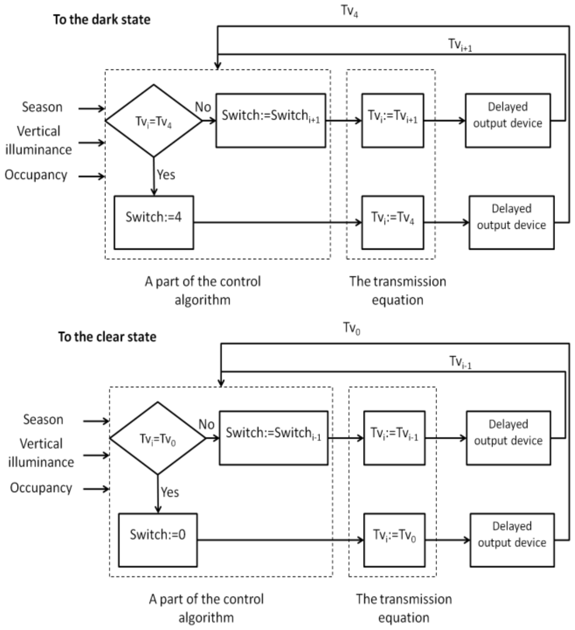

Figure 3 Integration of the switching dynamics to the control strategy

The glazing can never be maintained for more than 4 minutes in an intermediate state because the algorithm imposes to move to the dark state or maintain in it, or to move to the clear state or maintain in it. Figure 4 represents different cases of switching. It is taken from TRNSYS simulations.

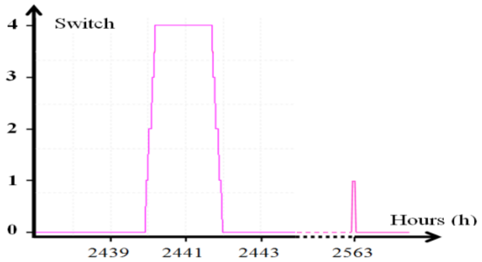

Figure 4 Different cases of switching from TRNSYS simulations. At left the window switches from clear to dark, maintains at dark state and switches from dark to clear. At right the window switches from clear to the first intermediate state and switches back to the clear state.

The energy systems

Occupancy time is from 8am to 6pm from Monday to Friday. Table 4 summarizes the HVAC system parameters for the offices. The circulation area is neither heated nor cooled, but it is ventilated with air change rate equal to $1.29h^{-1}$ during occupancy time.

Table 4
HVAC parameters

SYSTEM	CONTROL	SETPOINT
Heating		
Temperature	Perfect	20°C occupancy time 16° vacancy time
Humidity	No control	
Cooling		
Temperature	Perfect	25°C occupancy time 35°C vacancy time
Humidity	No control	
Double flow ventilation		
Air change rate	Perfect	$1.96h^{-1}$ occupancy time 0 vacancy time
By-pass	See algorithm figure 5	

The double-flow ventilation efficiency is 65%. A bypass system is used to take advantage of cooling provided by the outside air. The operation algorithm is shown in figure 5. The simulations also dealt with the case where no mechanical cooling was used. In this configuration we treated two cases: the building was cooled by using night ventilation provided by the mechanical ventilation: $1.96h^{-1}$, or it was not cooled at all. In this way we were able to study the contribution of electrochromic windows coupled with night ventilation and without night ventilation.

The lighting system used is managed according to a dimming control. Indeed, the electrochromic technology is a new one and should be designed for "modern" buildings.

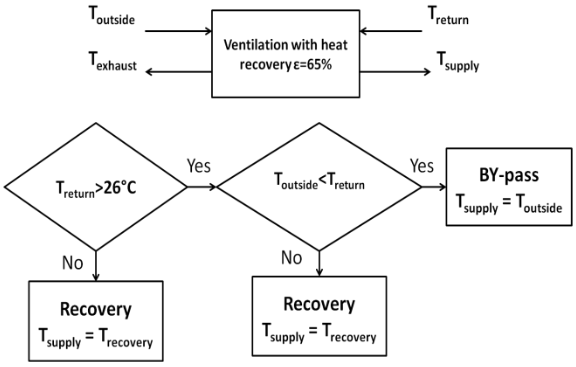

Figure 5 Algorithm for the by-pass operation

In addition, this will allow us to assess the lighting consumption and we will compare it to that of the same building equipped with a reference clear glazing. In Wallonia, for passive buildings, the part of lighting consumption can exceed that due to heating and cooling together (Goetghebuer, 2015). The luminous efficiency of the lighting system has a significant impact on the lighting consumption and the results of the simulations. This efficiency can vary from 10lm/W to 110lm/W depending on the technology of the lighting system (Deneyer et al., 2011). We chose, for the simulation, a luminous efficiency equal to 60lm/W and artificial lighting gain equal to $5W/m^2$. The lighting system is simply controlled by using a hysteresis-type function: if the average indoor daylight illuminance is less than 300lux during occupancy time then artificial lighting is used in addition to achieve 400lux. When the average indoor daylight illuminance reaches 400lux, artificial lighting is disabled.

Visual comfort in TRNSYS

The weather files used by TRNSYS only provide the global horizontal illuminance measured in the absence of obstruction. Then TRNSYS calculates horizontal diffuse and direct illuminances by using a statistical model. But TRNSYS does not have any model to assess the illuminance on an inclined surface as it does for the irradiation. So we assessed the vertical diffuse illuminance from the horizontal diffuse illuminance provided by the TRNSYS weather file by using a model chosen in the scientific literature. Then we assessed the vertical direct and reflected illuminances from the horizontal direct illuminance and geometric considerations. After this we assessed the average indoor illuminance by using a simple balance of the daylight entering the office.

Calculation of the global vertical illuminance

Several models for assessing diffuse vertical illuminance (Muneer, 2004) from the diffuse horizontal illuminance exist. We chose to implement the Perez model (Muneer, 2004; Perez et al., 1988; Robledo et al., 1997). According to Perez model, the diffuse illuminance on an inclined surface, with a slope β, is:

$$E_{d,\beta} = E_d\,[0.5\,(1-F_1)\,(1 + \cos\beta) + (a/b)\,F_1+F_2\sin\beta] \qquad (4)$$

$$F_1 = \max\,[0, (F_{11} + F_{12}\Delta + (\pi/180)\,Z\,F_{13})] \qquad (5)$$

$$F_2 = F_{21} + F_{22}\,\Delta + (\pi/180)\,Z\,F_{23} \qquad (6)$$

In the point source version of the Perez model the coefficients a and b are simplified (Robledo et al., 1997). That means that the circumsolar radiation is considered to be from a point source (Muneer, 2004). In this case a and b are expressed by the following simple equations: $a = \max\,[0, \cos\Theta]$ and $b = \max\,[\cos 85°, \cos Z]$. F_1 and F_2 are the brightness coefficients. They represent the degree of anisotropy of the circumsolar and the horizon regions. Δ is the sky brightness and it is defined by the following equation: $\Delta = E_d\,AM / E_0$, where E_0 is the mean extraterrestrial normal illuminance defined by the following equation: $E_0 = 128000lux\,[1 + 0.033412\,\cos(360n/365)]$ (Kandilli et al., 2008) with n the number of the day of the year. AM is the optical air mass. This concept is explained in detail in (Günther, 2011). $AM = \exp(-0.0001184.h)/\,(\cos Z+0.51(93.885-Z))^{-1.253}$. The Fij coefficients were experimentally evaluated by Perez (Perez et al., 1988) for multiple sites. The results show that they mainly depend on the clearness index and the altitude angle of the site. However, he evaluates some Fij coefficients that are a good approximation whatever the considered site. They are given in (Muneer, 2004). As the glazed surfaces considered for the simulation are vertical, the Perez equation is simplified:

$$E_{d,v} = E_d\,[0.5\,(1-F_1) + (a/b)\,F_1 + F_2] \qquad (7)$$

Note that the Perez equation used for illuminance is the same as that used for irradiance. This is one of the models used by TRNSYS to assess diffuse irradiance on tilted surfaces. These are the F_{ij} coefficients that are different. The sky brightness is also different because it is defined according to illuminance parameters and not according to irradiation parameters.

The global vertical illuminance is the sum of the vertical diffuse illuminance, the vertical direct illuminance and the reflected global illuminance from the ground to the vertical:

$$E_{g,v} = E_{d,v} + E_{b,v} + E_{r,v} \qquad (8)$$

$$E_{b,v} = E_n \max\,[0,\cos\beta] \qquad (9)$$

$$E_{r,v} = 0.5\,\rho\,E_g \qquad (10)$$

Calculation of the average indoor daylight illuminance (Little fair, 1981)

To evaluate the average indoor daylight illuminance, the author in (Little fair, 1981) achieves a balance of light flux entering the room through a window. The flux entering the room is $E_{gv}\,T_v\,W$, where T_v is the visible transmittance of the window and W the window area. The flux striking indoor surfaces is $E_{in}\,A$, where E_{in} is the average indoor daylight illuminance on all the room surfaces and A is the total area of all indoor surfaces, ceiling, floor, walls and windows. The flux absorbed by the indoor surfaces is $E_{in}\,A\,(1-R)$, where R is the area-weighted mean reflectance of all the surfaces. The flux entering the room equals the flux absorbed: $E_{gv}\,T_v\,W = E_{in}\,A\,(1-R)$. This gives the average indoor daylight illuminance:

$$E_{in} = (W\,T_v\,E_{gv}) / [A\,(1-R)] \qquad (9)$$

The control algorithm

Sensors used to control the electrochromic glazings are an outdoor temperature sensor and a luxmeter measuring illuminance on the glazed façade (figure 1). The outdoor temperature measurement is used to define two seasons: the summer season when the priority is to remove overheating and the winter season when the priority is given to visual comfort. We define the seasons by using the running average outdoor temperature over 24 hours. This idea was introduced in (Guillemin et al., 2001). We consider that the season, if the average temperature over 24 hours is greater than 12°C, is summer. If this average temperature is below than 10°C then it is winter.

Between 10°C and 12°C, the season is the same as that of the previous state (hysteresis function). In summer, the algorithm orders the electrochromic glazing to move to dark state. In winter, during vacancy time the glazing moves to clear state so that the building takes advantage of solar gain. During occupancy time, in winter, the priority is given to visual comfort. If the measured vertical global illuminance is greater than 30000lux, then the glazing moves to dark state. If the measured vertical global illuminance is lower than 20000lux, then the glazing passes to clear state. The transition from a state to the next one follows the dynamics described in section 1. Between 20000lux and 30000lux, the glazing remains at the state in which it was previously (hysteresis function). The illuminance considered is the running average illuminance over fifteen minutes. Figure 6 represents the control algorithm.

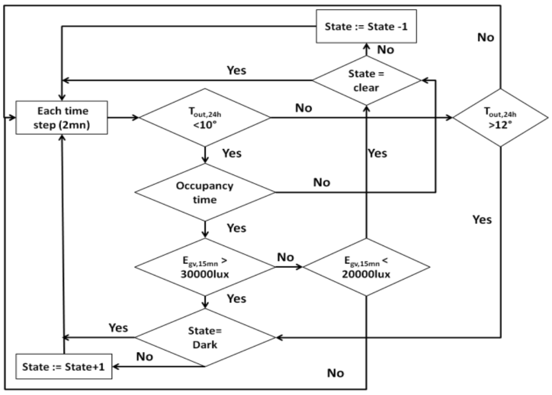

Figure 6 Electrochromic glazing control algorithm

DISCUSSION AND RESULT ANALYSIS

Figure 7 represents primary energy consumptions of the entire floor and the southwest office (meeting). For these simulations, night ventilation was not turned. The primary energy consumption was assessed using a conversion factor equal to 2.5 for passing from electrical kWh to gas primary kWh and a factor equal to 1.1 for assessing the gas primary kWh from thermal kWh calculated by TRNSYS simulations.

The primary energy consumption of the floor equipped with the reference clear glazing drops from 100.9kWh/m^2.y to 38.6kWh/m^2.y when it is equipped with the electrochromic glazings. The great difference comes from cooling consumption which dropped from 82.7kWh/m^2.y to 7.9kWh/m^2.y for the entire floor through the use of the electrochromic glazing. This is because of the great difference between the solar heat gain factors in summer: 0.15 for the electrochromic glazing at dark state and 0.71 for the reference glazing. The heating consumption of the building equipped with the electrochromic glazing is greater than that of the one equipped with the reference glazing because the solar heat gain factor of the electrochromic glazing is much lower than that of the reference glazing and because the priority for the control is given to visual comfort in winter. However it does not impact the total energy balance because of the importance of the cooling consumption for the building equipped with clear glazing. Remember that the building is highly glazed. The lighting consumption of the building equipped with an electrochromic glazing is higher than that of the one equipped with a clear glazing particularly the south west office which is about twice as much as that of the same office equipped with clear glazing: 11.3kWh/m^2.y versus 5.8kWh/m^2.y. The lighting consumption of the office which is equipped with electrochromic glazing represents 25% of the total consumption while the lighting consumption of the office which is equipped with clear glazing only represents 4.7% of the total consumption which explains that the lighting consumption does not impact a lot on the energy balance. If the building thermal efficiency is high then the lighting consumption can have an important impact on the total energy balance, even though this statement may be challenged by the LED technology whose luminous efficiency could quickly reach 200lm/W and which is well adapted to dimming control (Vandermeersch, 2015; Deneyer, 2015).

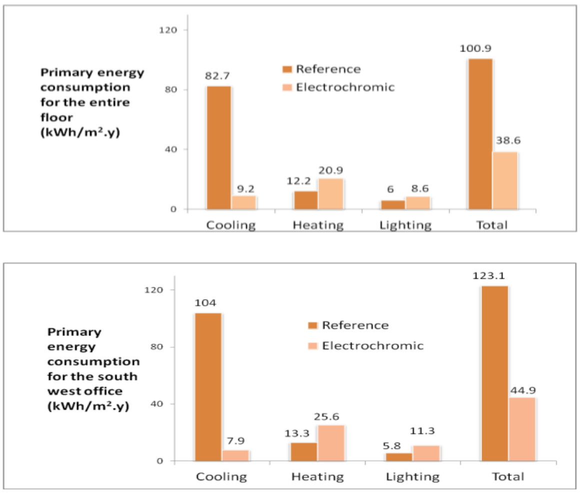

Figure 7 Comparison of the electrochromic glazing and the clear reference glazing in terms of primary energy consumptions

Then the air conditioning was turned off. We studied two cases. 1: With night ventilation, provided by an air change rate equivalent to 1.96h^{-1} the same as the one used during occupancy time so that it is simply achievable by the mechanical ventilation system. 2: Without night ventilation. Figure 8 shows cumulative frequencies of operative temperatures within the southwest office in non-heating season when the office is equipped with electrochromic glazing.

If we suppose that the summer comfort temperature is 26°C, then the overheating risk is 10% with night cooling while it is 34% without night cooling. With night ventilation, operative temperatures never exceed 28°C. Without night cooling, they never exceed 29°C. The use of night ventilation reduces operative temperatures by 1K to 1.5K. The same simulations were performed with the clear glazing. They showed that with night ventilation, the overheating risk is 40% the whole year and operative temperatures could reach 37°C. Therefore, we can conclude that electrochromic glazing combined with low night ventilation would remove overheating and would avoid the use of mechanical cooling without the increase in lighting consumption and heating has a significant impact on the building energy balance.

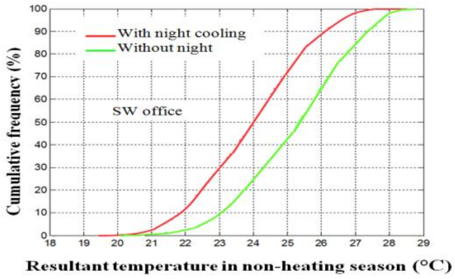

Figure 8 Cumulative frequencies of operative temperatures within the southwest office in non-heating season. The office is equipped with electrochromic glazing. Comparison of both cases: with night ventilation and without night ventilation.

The last part of the research consists of studying the visual comfort. We compared the southwest office with the northwest one with electrochromic glazing and with clear glazing. Figure 9 represents cumulative frequencies of average indoor daylight illuminances for both offices with electrochromic glazing during one year in occupancy time.

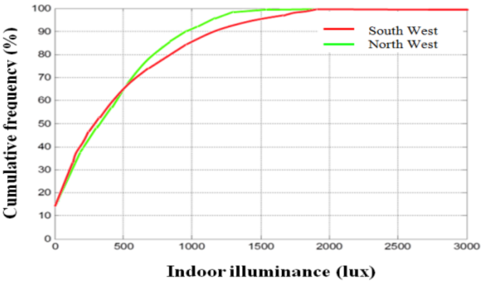

Figure 9 Cumulative frequencies of average indoor daylight illuminances for southwest and northwest offices for one year in occupancy time. Both offices are equipped with electrochromic glazing.

Figure 9 shows that the indoor daylight illuminance is lower than 2000lux all the occupancy time. The 1000lux value is exceeded between 7% and 14% of the time depending on the office. From the cumulative frequencies of illuminances, we assess the daylight autonomy (*DA*) taking into account illuminances greater than 300lux, and the useful daylight illuminance (*UDI*) taking into account illuminances between 300 and 3000lux. If illuminance is greater than 3000lux then there is over-illumination; if illuminance is less than 300lux then the office is not autonomous in daylight and it needs artificial lighting, which means electricity consumption. As illuminances are every time lower than 3000lux then *UDI=DA*. It is between 45% and 50% depending on the office. According to (Michel, 1999), 300lux is the minimum average illuminance to work in an office. For an office work, in front a computer screen, according to the same author, the maximum acceptable illuminance is 1000lux. However, figure 9 shows that there is no risk of over-illumination and daylight autonomy is quite good. We performed the same simulations for both offices equipped with the clear glazing. All results are summarized in Table 5.

Table 5
Visual comfort in southwest and northwest offices

	DA	**UDI**	**Over-illumination**	**1000lux**
Electrochromic	45-50%	45-50%	0%	7-14%
Clear	80%	55-75%	5-25%	58%

When both offices are equipped with the clear glazing there is a risk of over-illumination particularly for the southwest office for which the risk is 25%. The *DA=80%* is high which means a high autonomy in daylight and a low need of artificial lighting. That confirms results about lighting consumption presented at the beginning of the section. In both offices the 1000lux value is exceeded 58% of the time, which means that for office work, the occupant may be highly disturbed.

CONCLUSION

This research was the opportunity to study two different but connected aspects of comfort in TRNSYS: thermal comfort and visual comfort. We particularly implemented a combination of two existing models in TRNSYS to assess the average indoor daylight illuminance. For this, we calculated the vertical diffuse illuminance by using a Perez model. Another approach is possible; we could assess the sky luminance for different skies. (Ne'eman, 1983) presents luminance models for different types of sky: overcast sky, sunny sky, intermediate sky. Then we calculated the average indoor daylight illuminance by using a simple balance of the light entering the office. Other correlations between global vertical outdoor illuminance and indoor daylight illuminance exist. It could also be implemented in TRNSYS. In this research, we simulated electrochromic windows in TRNSYS and their switching dynamic. The dynamic of switch was simulated by using the light transmittance of the glazing for an incidence angle equal to 0. The model could be improved by using transmittances corresponding to different incidence angles. These data exist in TRNBUILD. The dynamic of switch could also be improved if the linear dynamic was replaced by an exponential one. From the measurement of the outdoor temperature and that of the vertical outdoor illuminance, we implemented a control strategy for electrochromic glazings taking into account the dynamics of the switch. Simulations show that electrochromic glazings allow to drastically reduce primary energy consumption of the simulated office building. This consumption is partly due to cooling. Although heating and lighting consumption increase with electrochromic glazing, they do not have a significant impact on the building energy balance. Simulations highlighted the benefit of electrochromic glazing in removing overheating, especially when coupled with low flow rate night ventilation. Electrochromic glazing would avoid using mechanical cooling. Simulations also showed that electrochromic glazing would eliminate over-illumination in an office, while maintaining quite good daylight autonomy. We went thoroughly through this aspect with an experimental study in which we measured indoor illuminances at different locations within two scale models of an office. The offices were equipped with the electrochromic glazing which was controlled according to the strategy presented in this paper and with the clear glazing. We also measured luminances to assess glare risk. This experimental study will be shortly published.

NOMENCLATURE

T = temperature
T_v = visible transmittance
$E_{d,\beta}$ = diffuse illuminance on an inclined surface
β = slope of the inclined surface
Z = solar zenith angle
Θ = incidence angle
E_d = normal diffuse illuminance
$E_{d,v}$ = vertical diffuse illuminance
$E_{g,v}$ = vertical global illuminance
$E_{r,v}$ = reflected global illuminance
Δ = sky brightness
F_1, F_2 = brightness coefficients

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