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A Study on the Proper Position of Illumination Sensor for Dimming Lighting Control Based on Practical Life: Focusing on Summer Solstice and Winter Solstice

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Abstract

Due to recent increase in energy consumption of lighting, the energy consumption in the building sector is shown high, reaching 34% of total energy consumption. Although a variety of technologies have been on the rise and increased to which IT technology is applied as an alternative to reduce the lighting energy the lighting control technology for energy saving has been limited. And in investigation on existing previous studies, some nonconformities have been found out at the position of illumination sensor. So, in this study, there was derived each position of illumination sensor at the summer solstice and the winter solstice Although a variety of studies for lighting energy saving has been on the rise and increased due to increase in energy consumption of lighting in building sector they are carried out in a limited environment of technology development in the lighting energy. In an investigation on existing previous studies, it has been found out that the position of illumination sensor for control was derived on the basis of work surfaces and eye-level illumination, so in this study, it is intended to construct the foundation materials for lighting control after deriving the position of illumination sensor for dimming lighting control in real life. In this study, there was conducted a performance evaluation through the construction of test bed on a real life basis and the illumination range for lighting control was set to 400 lx on the basis of the KS A 3011. The conclusion is as follows. 1) At the summer solstice, S11 position 1,000mm away from a skylight is shown as a proper position of illumination-environmental collection for dimming lighting control. 2) At the winter solstice, the dimming lighting control is unnecessary, but S1~S3 positions within the range of 5,000mm~6,000mm are shown as proper positions of illumination-environment collection for dimming lighting control. 3) When generalizing the results shown at the summer solstice and the winter solstice, S11 position 1,000mm away from a skylight is shown as a proper position of illumination-environment collection for dimming lighting control. 4) As a result of effectiveness at S11position, energy saving can be attained by 16~44% compared to other positions, and the analysis is carried out effectively. Therefore, it is determined that in the future study it will be necessary to supplement by conducting a performance verification in accordance with illumination standards for lighting control and diverse time zones as well as lighting control positions.

Keywords: *Dimming control, Practical life dimming light control, Performance evaluation*

1. Introduction

Due to recent increases in energy consumption, the building sector now is estimated to consume nearly 34% of total energy consumption. This is especially true for lighting which accounts for approximately 20% of the total energy consumption of buildings[1]. Although a variety of studies has been on the rise and

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increased to which IT technology is applied as an alternative to reduce the lighting energy, the development of lighting control technology for energy saving has been conducted only limited to a laboratory environment, and in an investigation on existing previous studies, it has been found out that the position of illumination sensor for control was derived on the basis of work surfaces and eye-level illumination [2]. This shows that the position of illumination sensor may be inappropriate from the aspect that the position of illumination sensor for lighting control should be installed at the ceiling or wall surfaces in the real life environment. [3].

So, in this study it is intended to derive, compare and analyze the position of illumination sensor at the summer solstice and the winter solstice, and on this basis in this study, it is aimed to construct and utilize the foundation materials in order to verify the position of illumination sensor for dimming lighting control in a real life

2. Theoretical Investigation on Lighting Control

2.1. Method of Lighting Control

As shown in Table 1, the method of lighting control may be classified into an individual control, a group control, a pattern control, a link control, a control by a detection sensor, a time-schedule control, a situation control, a control by a sensor, a remote control and a dimming control [4, 5]. Of these, a dimming control – which applies to this study, is a control technology enabling the efficient control and brightness adjustment of lighting energy – can provide a custom-designed illumination by providing the illumination by level.

Table 1. Classification of Control Method

Control method	Description
Individual Control	- Control of the individual light load by use of each switch - Control of the individual light load by use of the switch at various places - Through the feedback of switch mode state, the state of each switch is synchronized.
Group Control	- Simultaneous on/off control through the grouping of lighting at a certain place - Load control for free range in conformity to changes in the space in use
Pattern Control	- Function to operate the lighting through the grouping in a chosen pattern - Free changes in the range of light-on/off and blink
Link Control	- Control of the lighting at a specific area through linkage with the method of electric power for equipment, etc.
Control by a Detection Sensor,	- Control of the light-on/off for lighting in accordance with detection of objects after the installation of an operating sensor at a specific area
Time-Schedule Control,	- Automatic control of the light-on/off in accordance with a regular schedule
Control by Illumination Sensor	- Automatic control of the light in accordance with the natural light illumination of illumination sensor
Remote Control	- Monitoring and control by use of internet and other

	communication network at a far distance
Situation Control	- Control in conformity to a situation after setting a lighting situation appropriate for the purpose of use
Dimming Control	- Control enabling the efficient control and brightness adjustment for lighting energy

2.2. Investigation on Illumination Standards

As shown in Table 2, the indoor proper illumination in Korea is presented by the KS A 3011. The KS A 3011 specifies the illumination range in accordance with activity type and method of lighting on work surfaces, and the illumination range is represented as minimum illumination - average illumination - maximum illumination. So, in this study, 400 lx was set as the standard for dimming lighting control based on the contents of visual work execution compared to general brightness or targeted for small objects.

Table 2. Standard Illuminance of KS A 3011

Type of activity	Scope (lx)			Illumination method of work plane
	Minimum	Average	Maximum	
Execution of visual work in comparison with high-brightness or targeted for large objects	150	200	300	Illumination of work Plane
Visual performance according to the degree of general brightness	300	400	600	
Execution of visual work in comparison with low-brightness or targeted for very small objects	600	1000	1500	

3. Derivation of the Position for Illumination Sensor and Verification of Effectiveness for Lighting Control

In this study, there was constructed a test bed for derivation of the position of illumination sensor and verification of effectiveness for lighting control and there was conducted a verification of effectiveness by calculating the indoor illumination distribution and electricity consumption in accordance with the position of illumination sensor for lighting control.

3.1. Construction of Test-bed on a Real Life Basis

In this study, there was constructed a real life test bed for concluding lighting control and electricity consumption by level, satisfying the verified indoor lighting illumination at the summer solstice and the winter solstice, and the summary is shown in Table 3 below. As the formation of external light environments is shown in Table 4, in this study the artificial solar light was constructed, and the formation of external light environment at the summer solstice and the winter solstice was conducted by adjusting the light volume, angle and height, etc. of the artificial solar light.

Table 3. Overview of Test-bed

Category	Key Attributes
Area Size	4.9m(W) * 6.6m(D), 2.5m(H)
Window	Size : 2.2m(W) * 1.8m(H) Material : Pair glass, 12mm
Season	Summer Solstice, Winter Solstice
Direction	South

The specification of illumination sensor applied to this study is shown in Table 4, and a three-dimensional monitoring of environment information is available.

Table 4. Specification of Illumination Sensor for Test-bed

	Spec
Illumination Sensor	- Detection element: Silicon photo sensor, with filter - Detection range: 0~20,000lx - Response time: 300ms. Allowable ambient temperature: -40~65 ℃ - Output signal: 4~20ma dc Two wire. Precision level: ±3%

As the summary of lighting applied to this study is shown in Table 5, the dimming 8 levels are controlled at illumination-off, and the electricity consumption by level is shown in Table 6.

Table 5. Spec of Lighting

	Spec
Lighting	Lighting 4EA, dimming lighting control Lv1~8

Table 6. Electricity Consumption to the Illumination Dimming Level

Dimming Level	Electricity consumption(W)
Lv 1	12.33
Lv 2	18.31
Lv 3	22.04

Lv 4	27.65
Lv 5	34.00
Lv 6	38.48
Lv 7	42.59
Lv 8	50.81

3.2. Selection of Position of Illumination Sensor for Dimming Lighting Control

3.2.1. Selection of Position of Illumination Sensor for Dimming Lighting Control: As seen in Fig 1 in this study, an illumination sensor installed on the ceiling surface was taken into consideration, and 12 measuring points in total were selected at the intervals of 500mm from the window, which took into consideration the spatial depth within a test bed. For dimming lighting control, if the illumination value was less than 400 lx set as the standard based on the contents of visual work execution compared to general brightness or targeted for small objects, the dimming lighting control was conducted in sequence, and if the value is more than 400 lx, the dimming lighting control was discontinued.

3.2.2. Selection of Position of Illumination on Work Surfaces for Effectiveness Verification: In this study, for the effectiveness verification, the dimming lighting control was conducted at the summer solstice and the winter solstice, respectively for the positions of illumination sensor selected in the above. In this study, the dimming lighting control was conducted from the darkest position based on illumination formed in accordance with the influx of natural light, and the lighting control was conducted in sequence for the illumination sensor located on indoor work surfaces to satisfy 400 lx.

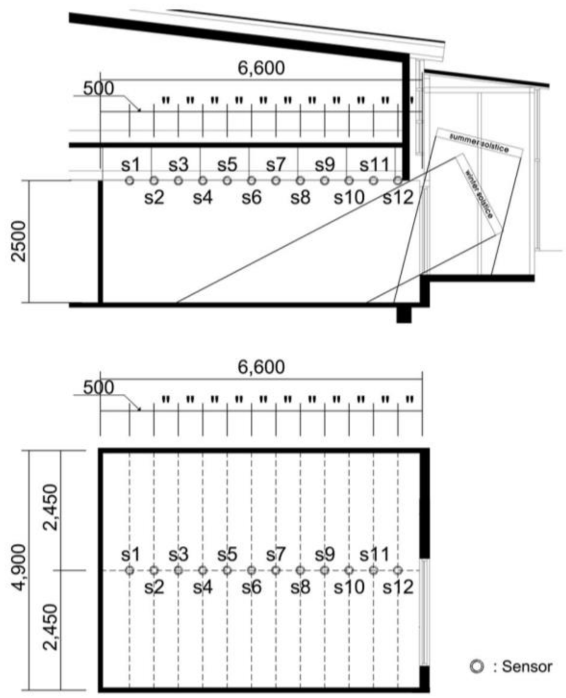

Figure 1. Position of Illumination Sensor for Dimming Lighting Control

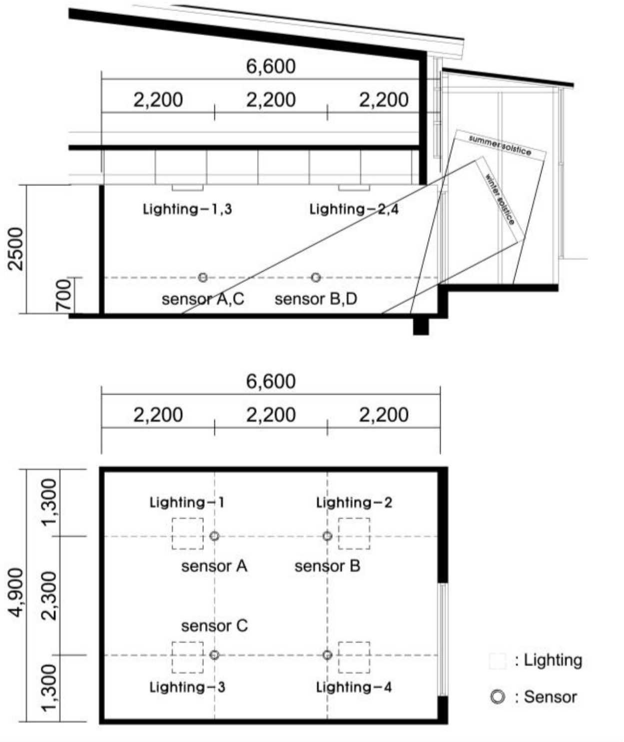

Figure 2. Position and Lighting and Illumination Sensor for Performance Evaluation

3.3. Results of Analysis on Calculation of Electricity Consumption based on the Results of Illumination Measurement

3.3.1. Results of Analysis on Calculation of Electricity Consumption based on the Results of Illumination Measurement at the Summer: For the summer solstice, the measures values of indoor illumination distribution for the test bed constructed in this study is shown in Table 7, and as shown in Table 8, it was verified that the dimming control was necessary within the range excluding S 12 on the basis of illumination values measured for the ceiling surface. In addition, as shown in Table 9, as a result of calculation of electricity consumption in accordance with lighting control, S11, which is 1,000mm away from a skylight, was represented as a proper position of illumination-environment collection for dimming lighting control.

Table 7. Lighting in Accordance with Measured Values of Indoor Control and Control of Electricity Consumption at the Summer Solstice (Sensor A~D)

Sensor	Sensor A	Sensor B	Sensor C	Sensor D
Electrimcity Consumption (lx)	105.4	176.9	33.1	192.5

Table 8. Lighting on the Ceiling Surface at the Summer Solstice (Sensor 1~12)

Sensor	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Electrimcity consumption (lx)	20.0	20.0	21.5	63.7	71.2	72.9	78.2	175.3	218.9	236.2	326.2	605.5

Whether lighting control	O	O	O	O	O	O	O	O	O	O	O	X

Table 9. Lighting on the Ceiling Surface the Results of Measured Values for Illumination on the Ceiling Surface at Summer Solstice (Sensor 1~12)

Sensor	Dimming Lighting control (1~8lv)				Power consumption (kWh)	Indoor illuminace distribution according to lighting control (lx)			
	Lighting 1	Lighting 2	Lighting 3	Lighting 4		Sensor A	Sensor B	Sensor C	Sensor D
S1	Lv.8	Lv.8	Lv.8	Lv.8	203.24	583.7	687.5	547.5	716.0
S2	Lv.8	Lv.8	Lv.8	Lv.8	203.24	582.9	680.9	548.7	712.2
S3	Lv.8	Lv.8	Lv.8	Lv.8	203.24	578.9	673.7	545.9	711.2
S4	Lv.8	Lv.8	Lv.8	Lv.8	203.24	580.2	690.2	546.3	706.5
S5	Lv.8	Lv.8	Lv.8	Lv.8	203.24	595.5	675.2	557.2	706.8
S6	Lv.8	Lv.8	Lv.8	Lv.8	203.24	576.1	672.1	543.1	713.5
S7	Lv.8	Lv.8	Lv.8	Lv.8	203.24	583.2	679.2	546.9	715.0
S8	Lv.8	Lv.8	Lv.8	Lv.8	203.24	577.5	680.7	543.3	708.5
S9	Lv.8	Lv.8	Lv.8	Lv.8	203.24	579.1	681.5	548.2	709.2
S10	Lv.8	Lv.8	Lv.8	Lv.8	203.24	578.9	679.5	547.1	709.8
S11	Lv.8	Lv.8	Lv.8	Lv.2	170.74	557.5	603.5	525.2	491.7
S12	X	X	X	X	X	106.5	175.5	32.5	191.2

3.3.2. Results of Analysis on Calculation of Electricity Consumption based on the Results of Illumination Measurement at the Winter Solstice: For the winter solstice, the measures values of indoor illumination distribution for the test bed constructed in this study is shown in Table 10, and as shown in Table 11, the dimming lighting control is unnecessary on the basis of illumination values measured for the ceiling surface, but as shown in Table 12, as a result of calculation of electricity consumption in accordance with lighting control based on 400 lx set as the standards in this study, S1~S3, which are 5,000mm~6,000mm away from a skylight, were represented as a proper position of illumination-environment collection for dimming lighting control.

Table 10. Lighting in Accordance with Measured Values of Indoor Control and Control of Electricity Consumption at the Winter Solstice (Sensor A~D)

Sensor	Sensor A	Sensor B	Sensor C	Sensor D
Electrimcity Consumption (lx)	508.1	651.2	1839.2	606.5

Table 11. Lighting on the Ceiling Surface at the Winter Solstice (Sensor 1~12)

Sensor	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
Electrimcity consumption	248.2	260.7	353.7	408.5	473.2	478.7	588.9	645.0	661.7	677.5	906.2	947.2

(lx)												
Whether lighting control	O	O	O	X	X	X	X	X	X	X	X	X

Table 12. Lighting on the Ceiling Surface the Results of Measured Values for Illumination on the Ceiling Surface at Winter Solstice (Sensor 1~12)

Sensor	Dimming Lighting control (1~8lv)				Power consumption (kWh)	Indoor illuminace distribution according to lighting control (lx)			
	Lighting 1	Lighting 2	Lighting 3	Lighting 4		Sensor A	Sensor B	Sensor C	Sensor D
S1	Lv.8	Lv.8	X	X	101.62	587.5	706.5	1943.2	890.2
S2	Lv.6	X	X	X	38.48	566.5	717.1	1938.7	886.2
S3	Lv.4	X	X	X	27.65	536.7	515.5	1842.9	520.0
S4 ~S12	X	X	X	X	X	508.1	651.2	1839.2	606.5

3.3.3. Position of Illumination Sensors in Accordance with the Results of Illumination Measurement and the Results of Analysis on Calculation of Electricity Consumption at the Summer and Winter Solstice: As a result of the above analysis, S11 position which is 1,000mm away from a skylight is shown as a proper position of illumination-environment collection for dimming lighting control at the summer and winter solstice, respectively, and the dimming lighting control for the collection of S11 illumination information is effective showing the 16~44% saving compared to illumination of dimming lighting control based on illumination information collected from other positions.

4. Conclusion

This study was to conclude of position of illumination sensor for dimming lighting control on a real life basis, and there was conducted a performance evaluation in consideration of position of lighting control and electricity consumption by level satisfying 400 lx set as the standards for dimming lighting control based on the contents of visual work execution compared to general brightness or targeted for small objects. The conclusion for result values derived thereafter is as follows.

First, at the summer solstice, S11 position, which is 1,000mm away from a skylight, is shown as a proper position of illumination-environment collection for dimming lighting control.

Second, at the winter solstice, the dimming lighting control is unnecessary, but S1~S3 positions within the range of 5,000mm~6,000mm are shown as proper positions of illumination-environment collection for dimming lighting control.

Third, when summarizing the results from the summer solstice and the winter solstice, S11 position which is 1,000mm away from a skylight is shown as a proper position of illumination-environment collection for dimming lighting control.

Fourth, as a result of the effectiveness at S11 position, energy saving can be attained by 16~44% compared to other positions, and the analysis is carried out effectively.

For the lighting control in this study, the study was carried out at 400 lx set as the standard for dimming lighting control based on the contents of visual work execution compared to general brightness or targeted for small objects. However, for the measured values of indoor illumination distribution at the summer and winter solstice respectively, the excessive illumination values were formed, and the measured illumination values of ceiling surface and indoor illumination distribution installed by the natural light illumination at the winter solstice mostly showed 400lx at a satisfactory level. Therefore, it is determined that in the future study it will be necessary to complement by conducting a performance verification in accordance with illumination standards for lighting control and diverse time zones as well as lighting control positions.

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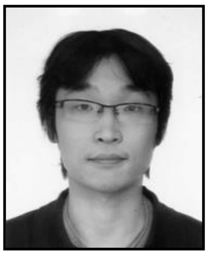

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