Electric power saving optimization simulation for the comfort of classroom lighting

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Abstract. Classroom lighting is one of the essential factors in learning process for students in a university. There are two types of lighting available to apply inside a classroom, i.e., natural and artificial lightings. This research aims to simulate classroom lighting management technology concerning Indonesia National Standard SNI 6197:2001 using Dialux software. The simulation result shows that the applied artificial lighting inside E11-210 room had not followed the standard yet, in 350 lux. The existence of both artificial and natural lightings has made E11-210 room were excessive in light intensity, despite successfully obeying the standard. This paper uses lamp power modification to optimize the light intensity efficiently without to infringe the standard. This paper also presents the potential benefit of implementing power modification in saving electricity usage costs for 56.94%.

1. Introduction

Indonesia is a developing country which is in the big four of nations with the highest population. Along with the large population that Indonesia has, the electricity needs also become fabulous. Based on the government's statistics [1], [2], the electricity consumption of Indonesia in 2017 was 267.454 GWh with projected average growth in electricity demand until 2027 will be about 10.1%. One of the most electricity consuming sectors is lighting sector.

For the past twenty years, research in lighting sector [3]–[8] has increased, especially in the utilization of outdoor lighting. There have been several methods to reduce electricity consumption in the lighting sector. They are replacing old and inefficient electrical-based tools with more recent ones, changing human's behavior in consuming electrical energy and applying advanced technology for electrical energy management. This paper focuses on simulation for electrical energy management technology based on the Indonesian National Standard (Standar Nasional Indonesia or so-called SNI) using Dialux. Considering SNI 6197:2011 [9], standard for lighting level in a classroom is 350 lux.

Classroom lightings implemented in E11-210, E11 building, Universitas Negeri Semarang are natural and artificial lighting. Teaching and learning process in the classroom practically run for 10 hours, from 07.00 AM to 05.00 PM. During the educational process, the room is utilizing both natural and artificial lightings simultaneously. Thus, classroom E11-210 has abundant lighting rate over the SNI 6197:2011. This occurrence causes the lighting activity in E11-210 is less efficient and not optimal. The study in this paper aims to provide a solution to overcome the efficiency problem and optimizing the lighting in E11-210 using Dialux to support efficient electricity consumption.

The remainder of this paper is organized as follows. In Section 2, the mechanical design of the robot arm is described together with the method used in this paper. Section 3 explains the experimental setup for conducting the functional test of the robot arm. The following part aims to present results and discussion that show the merit of the proposed design and method. It also elaborates how the robot arm was examined. Section 5 concludes the result and contribution of the paper.

2. Research Method

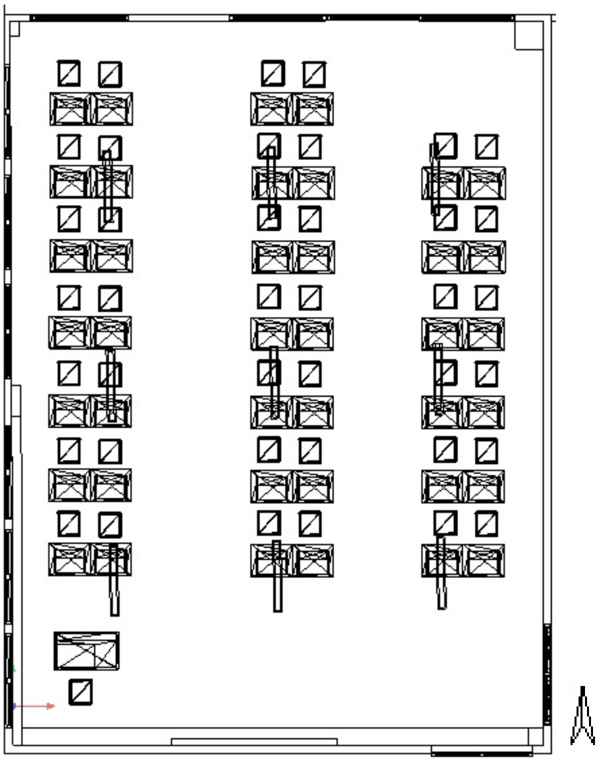
The determination of simulation variables in this paper is reviewed by two parameters, namely lighting type and the power of the utilized lamp in the classroom E11-210. Lighting type used in this simulation consists of two conditions, as presented in table 1.

Table 1. Lighting conditions employed in the simulation

Condition	Lighting type in classroom E11-210
1	Artificial Lighting
2	Artificial and Natural Lightings

The simulation applied general lighting measurement technique which the measurement of the lighting in every tested point was conducted by sensing the intensity of the light 1 meter above the floor. This work has corresponded with SNI 16-7062-2004 [10] for electing the gap among measuring points for the 96 square meter room E11-201 in 3 meters. The learning process in the classroom uses 18 Philips TCP 165 with nine armatures with the power of each mounted lamps in the simulation was 36 watts. Figure 1 (a) and (b) describes the illustration of the room E11-210 in the simulation.

(a)



(b)

Figure 1. The design of general lighting measurement of E11-210 classroom presented in (a) 3 Dimension and (b) 2 Dimensions

We simulated the general lighting measurement for condition two at 07.00 AM to 05.00 PM corresponding with the established lecturing time in Universitas Negeri Semarang. The simulation employed Dialux 4.12 in which the lighting type simulation used 2 conditions, as shown in table 2.

Table 2. The condition of the lamp electrical power parameters applied in the simulation

Condition	Applied lamp power
The real lamp power	36 watts
Modification of the lamp power	0 – 41 watts

Lamp power variable in the simulation has two conditions; they are the real lamp power and the modification of the lamp power, as listed in table 2. The practice of the modification in this simulation aims to adjust the lamp power efficiently and optimally for every hour between 07.00 AM and 05.00 PM. Therefore, the lighting of the room E11-210 can be corresponding with the minimum limitation, which SNI 6197:2011 stated, viz., 350 lux. This work also provides the expenditure projection of the E11-210 lighting with variation in lighting types and lamp power for a month at the cost of IDR 3720.00 per KWH (Kilo-Watt-Hour).

3. Result and Discussion

Figure 2 (a) to (b) are the simulation results of general lighting measurement in classroom E11-210 with artificial lighting. Based on Figure 2. (a) and (b), it can be seen that the average distribution of artificial light in E11-210 classroom was not corresponding SNI 6197: 2011 standard which was around 250-300 lux. In room E11-201 some windows can be used as additional lighting in classroom E11-210. With the application of artificial and natural light in E11-210 classroom, it was expected that E11-210 classroom lighting will be following SNI 6197: 2011 standards.

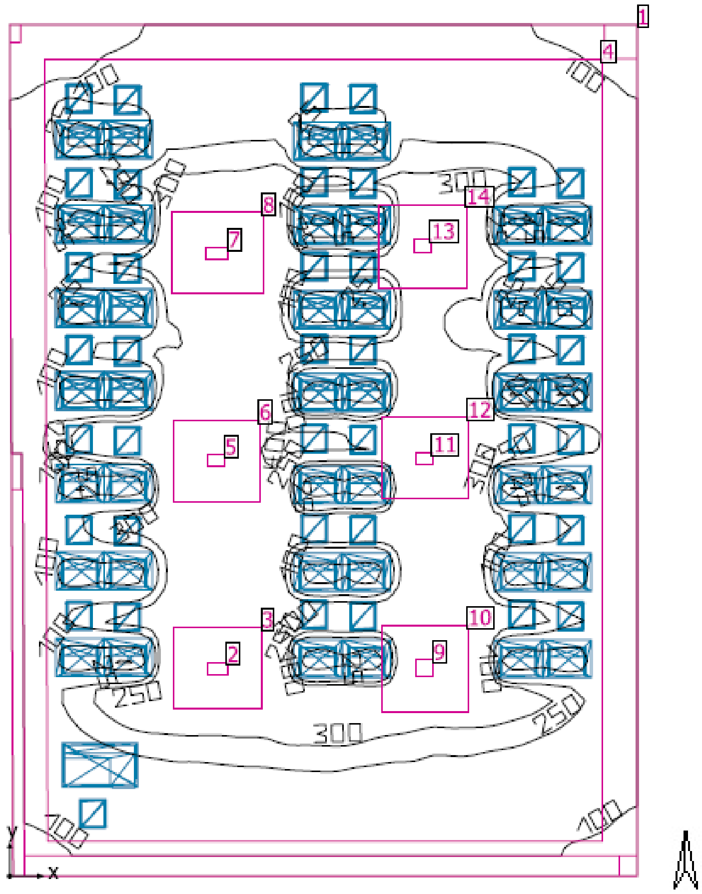
Based on table 3. it can be seen that from 1 to 4 PM in the E11-210 classroom, there was an excess light intensity of around 641-2244 lux. This was because the west side of the E11-210 class has 12 windows and no curtains so that sunlight could enter the room directly.

Table 3. Light intensity at general lighting measurement points at E11-210 using artificial and natural light sources

General lighting measurement points	Intensity per sampling hour (lux)										
	7 AM	8 AM	9 AM	10 AM	11 AM	12 AM	1 PM	2 PM	3 PM	4 PM	5 PM
1	707	833	840	762	506	746	1077	1471	2244	1494	663
2	617	708	738	693	731	723	1030	1453	1886	1361	662
3	518	606	627	604	600	646	886	1185	1599	1153	545
4	808	1004	1058	693	740	708	855	1049	1606	1426	693
5	579	703	722	891	601	612	718	936	1370	1153	610
6	483	533	548	656	640	519	641	767	1069	889	501

Shown in figure 3 (a). that tables and chairs near the windows have excessive lighting, which resulted in student inconvenience in the teaching and learning process. Figure 3 (b) was the distribution of room light intensity of E11-201 at 3 PM by using natural and artificial lighting. Based on the contours of the light intensity distribution, it can be seen that the use of natural and artificial lighting would make E11-210 classroom lighting in accordance with SNI 6197: 2011 standard. However, the E11-210 classroom at 1 to 4 PM had excessive light intensity so that modification of lamp power was needed to obtain optimal light intensity and efficient lamp power savings.

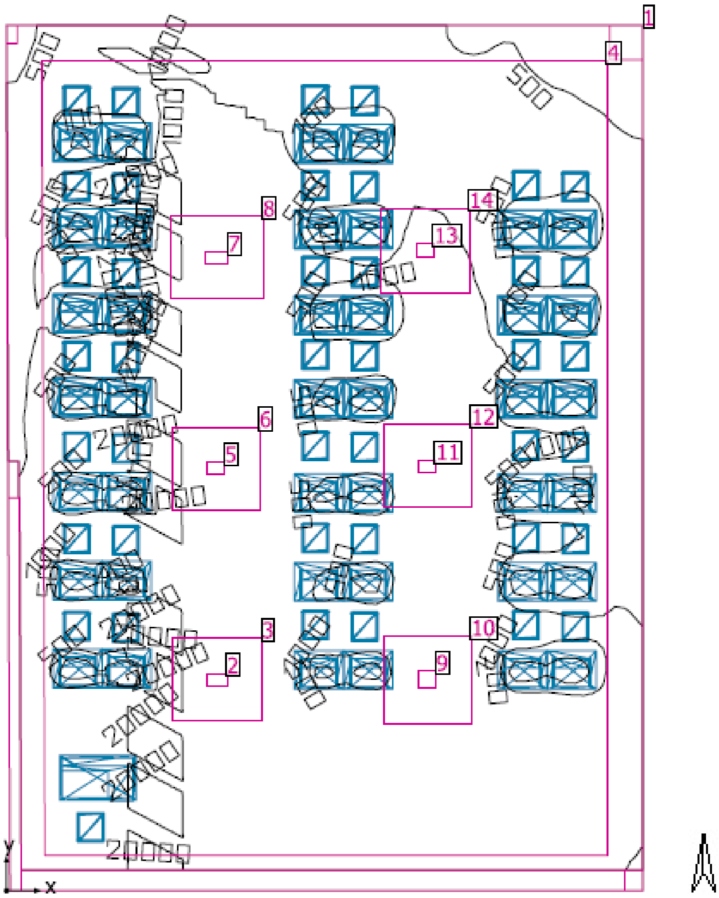
(a)



(b)

Figure 2. The artificial lighting of the room E11-210 in the form of (a) 3 Dimensions lighting and (b) Contour of Light Intensity Distribution

(a)



(b)

Figure 3. Artificial and natural lighting in E11-210 classrooms at 3 PM, presented in: (a) 3 Dimensions and (b) Contour of Light Intensity Distribution

Modification of lamp power could be seen in table 4, where the lamp power used was between 0 - 41 watts. The results of the simulation of lamp power modification at 7 AM to 5 PM could be seen in table 5, where the average light intensity was between 495-1209 lux. These results showed that the light intensity in E11-210 classroom was under SNI 6197: 2011 with the distribution of light intensity in every corner of the classroom at least 350 lux.

Table 4. Variation of lamp power modification which used in E11-210 classroom

Time	7 AM	8 AM	9 AM	10 AM	11 AM	12 AM	1 PM	2 PM	3 PM	4 PM	5 PM
Modified lamp power (watt)	41	29	26	26	23	6.5	10.5	7	0	1	0.5

Table 5. Light intensity at general lighting measurement points in E11-210 using natural lighting and modified power lamp of artificial lighting

General lighting measurement points	Intensity per sampling hour (lux)										
	7 AM	8 AM	9 AM	10 AM	11 AM	12 AM	1 PM	2 PM	3 PM	4 PM	5 PM
1	1093	984	983	915	825	785	925	1209	1917	1152	689
2	1082	917	890	879	801	738	865	1168	1551	989	657
3	946	796	758	755	701	655	740	935	1264	826	576
4	1230	1195	1131	1016	832	717	701	782	1244	1078	702
5	1050	897	880	799	702	610	557	659	1013	792	637
6	901	746	708	670	605	525	495	516	745	561	527

Based on the calculation of electricity costs in table 6, it could be seen that the use of electricity costs would be decreased by 56.94%. This was because from 12 AM to 5 PM the E11-210 classroom optimized the use of natural lighting more than artificial light. There were 12 windows on the west side of the classroom E11-210 so that the sunlight which entered the classroom could be optimized into natural light. Thus the electric power used could be optimal and efficient also the E11-210 classroom lighting could be by SNI 6197: 2011 standard.

Table 6. Daily electricity costs estimation with and without power lamp modification in the classroom E11-210

Time	The number of employed lamps	Costs per KWh (Rp)	Without Lamp Power Modification			With Lamp Power Modification		
			Lamp Power (Watt)	Total lamp power usage (Kwh)	Costs per hour (Rp)	Lamp Power (Watt)	Total lamp power usage (Kwh)	Costs per hour (Rp)
7 AM	18	3,720	36	0.648	2411	41	0.738	2745
8 AM			36	0.648	2411	29	0.522	1942
9 AM			36	0.648	2411	26	0.468	1741
10 AM			36	0.648	2411	26	0.468	1741
11 AM			36	0.648	2411	23	0.414	1540
12 AM			36	0.648	2411	6.5	0.117	435
1 PM			36	0.648	2411	10.5	0.189	703
2 PM			36	0.648	2411	7	0.126	469
3 PM			36	0.648	2411	0	0	0
4 PM			36	0.648	2411	1	0.018	67
5 PM			36	0.648	2411	0.5	0.009	33
			Total daily costs		26,516	Total daily costs		11,417

The lamp electrical power modification in table 6, could be applied using the Pulse Width Modulation (PWM) and Fuzzy Logic methods. This research was the initial stage for collecting data that would be used in making fuzzy logic and PWM algorithms. Therefore, the next phase of research would focus on making algorithms and implementing an automatic lamp power modification system in E11-210 classroom.

4. Conclusion

This paper declares that classroom E11-210 can use both natural and artificial lighting to tune efficiently the electricity consumption concerning SNI 6197:2011. This work also finds that lamp power modification from 0-41 watt in the room E11-210 can save electricity usage for 56,94 %. For future work, lamp power modification could be conducted using Pulse Width Modulation (PWM) and Fuzzy Logic. This research contributes to collect the most optimal lamp power database to support further study in implementing PWM and Fuzzy logic to the typical problem.

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Acknowledgments

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