Automated lighting design in the classroom

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ABSTRACT

Lamp automation is utilized to adjust the lighting in the classroom by adjusting to the level of sunlight intensity outside the classroom. The light intensity will be adjusted to the utilization of lights as indicated by the need to enlighten a room. Therefore, this research aims to depict the design of a light intensity measurement system using a BH1750 sensor that will be carried out to measure the intensity of sunlight in units of light (lux). The signal from the sensor will be transmitted to a mini pc which functions to process measurement data and display it on the graphical user interface (GUI). As a result, the sensor will instruct the dimmer as an actuator to control the classroom lights according to the lighting from the sun. This system is already installed in the classroom and can save energy around 35 kWh a year.

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1. INTRODUCTION

Waste in the consumption of electrical energy is often caused by negligence in turning off the light switch [1]. The automation on the lamp applied to provide energy efficiency [2]. Automation can be described as a sequential process with automatic feedback control to ensure proper execution with little or without human exertion [3]–[5]. The automation system consists of various sensors and actuator to observe the process [6], [7]. This research is based on the use of lights in the classroom, which is still operated manually, thus making waste in the use of electrical energy [8], [9]. Where the lighting in each zone of the classroom is still lit with the same intensity of illumination [10], [11]. The level of lighting in the room needs to be controlled, because there is already natural lighting from sunlight, therefore the lighting in the room needs to be automated [12]. So that the lighting can be adjusted to the use of lights according to the need to illuminate a room [13]. This relates to the fact in carrying out ongoing activities, that environmental activities provide important contextual information, and such environmentally intelligent behavior must be relevant to the user context [14].

The solar light intensity measurement system uses the BH7150 sensor module with light units (lux). The data results from sensor measurements will be processed by Arduino Uno controller whose role is to change the input signal from the light sensor which will be converted into a control signal on the actuator to regulate the lighting on the lamp. The controller is also used to process the measurement data and it will be displayed on the graphical user interface (GUI). The concept of this research is to design a lighting automation system that will be applied into 3 zones of the classroom, namely zone 1 in front of classroom, zone 2 in the middle of the classroom and zone 3 at the back of the classroom, which close to the window.

2. METHOD

2.1. Room lightening system

Lighting is generally divided into two types, namely natural lighting, and artificial lighting. The natural lighting can be light from the sun while artificial lighting comes from recognizable people-made light source with lamp lights [15]. There is a minimum standard at the recommended lighting for used in the room, namely the classroom 250 lux, 350 lux workspace [16], 300 lux meeting room, computer lab 350 lux, library 300 lux, laboratory 500 lux, drawing room 750 lux, and canteen 200 lux [17], [18].

2.2. Light automation system

The use of this light automation system will run automatically with sensors and controllers [19], which will be applied to the classroom. The explanation can be adapted to the use of appropriate lights with the need to illuminate a room. Lamp automation is used to set indoor lighting and adjust the lighting level outside [20]. This lamp automation can also adjust the level lighting needed in a room by adjusting the lighting standards and used to prevent waste of electrical energy [2]. Where the task concept was recently designed a lamp automation system that will be applied to 3 zones of the room, namely zone 1 in front of classroom, zone 2 in the middle of the classroom, and zone 3 at the back of the classroom which is close to the window, and it is shown in Figure 1. The type of lamp used in this study is an LED lamp. The dimensions of our classroom given by 7.1×10.4×3.1 m. The distance between each lamp with the light intensity BH1750 type sensor are 5 cm.

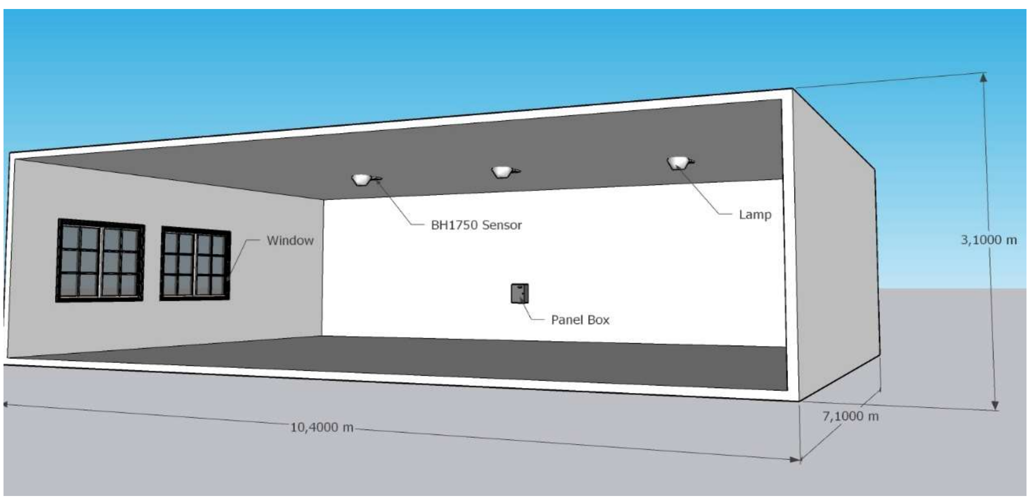

Figure 1. Design for implementing light automation in the classroom

The performance of this classroom lighting automation system involves testing all components that will be used to determine whether the tool is able to work properly and produce the desired output. The indicator of the success of this tool is to provide output in the form of lamp automation, where the lamp will turn on if there is minimal lighting and the lamp will dim if the light has met the predetermined set point. This lighting automation will be applied to 3 zones of the classroom, which will be optimized at the back zone lamp of the classroom which is close to the window due to direct sunlight. The close loop control diagram of the lamp is shown in Figure 2.

The lamp automation design uses the BH1750 sensor, and it will be installed in 3 room zones. Where the sensing results from 3 BH1750 sensors will be used as a set point for the amount of light intensity which will be converted by the controller as an actuator input signal [21]. The controller has a function to control the lamp in order to brighten or dim the lamp. The actuator will regulate the amount of voltage used in the room lights. So that 3 zones of room lights can be lit according to a predetermined room lighting standard of 300 lux [22]–[24].

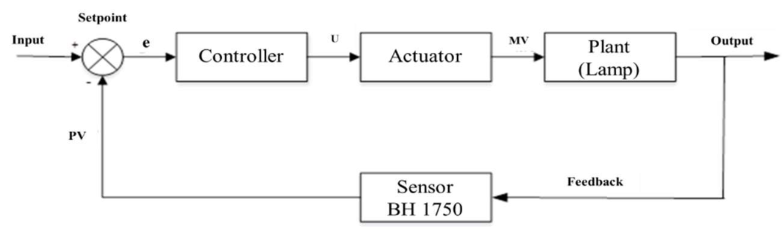

Figure 2. Closed-loop block diagram of automatic light control system

2.3. Light intensity measurement system

Figures 3 and 4 shows the measurement block diagram of lamp automation. The block diagram consists of input in the form of light intensity from the BH1750 light sensor module which located from 5 cm a way from the lamp, then the measurement results will be processed by the Arduino Uno controller which functions to change the input signal from the light sensor, and it converted into a control signal on the dimmer as an actuator for adjust the lighting on the lamp. The measurement data from the sensor transmitted by the controller so that it can be displayed on the GUI. The BH1750 sensor module in the form of a photodiode circuit in which an amplifier is used as a signal amplifier, then there is an ADC to convert analog signals to digital, and there is I2C which is used to display the results of light measurements in unit of lux from the sensor [25], [26].

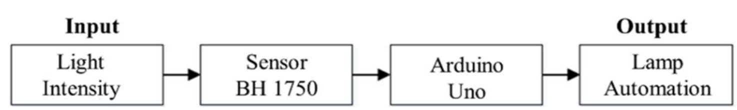

Figure 3. The measurement block diagram of lamp automation

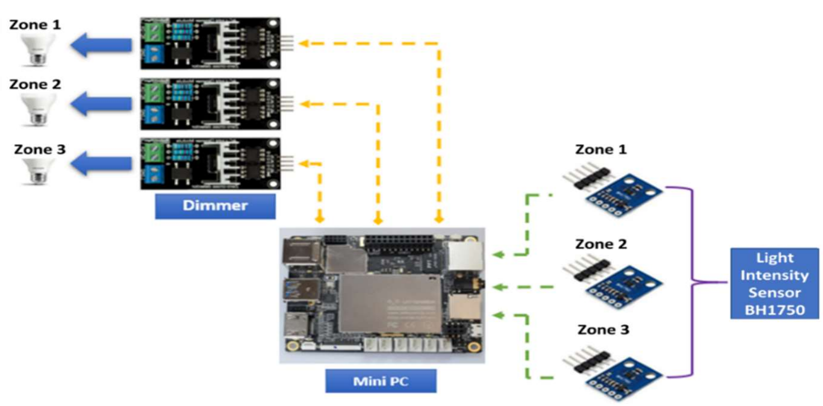

Figure 4. The measurement wiring diagram of lamp automation

3. RESULTS AND DISCUSSION

3.1. Graphical user interface of light intensity measurement

The GUI display design for light intensity measurement is shown in Figure 5, where the light intensity measurement value will be displayed on the GUI display with units of lux in 3 zones of the classroom. On the GUI display there are red, green, and yellow light indicators, which are used to determine the lux result from the light sensor output according to the set point. If the lux result of the light measurement is 300 lux then the green indicator lights up according to a predetermined set point, if the sensor result is higher than 300 lux then the red indicator lights up, the dimmer actuator will decrease the intensity of the lamp and if the sensor result is lower to 300 lux then the yellow indicator lights up and the dimmer actuator will increase the intensiy of lamp untill the intensity is 300 lux.

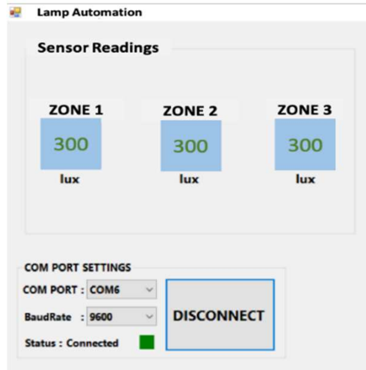

Figure 5. The GUI display of the light intensity monitoring system in the classroom

3.2. Validation of BH1750 light sensor using luxmeter

The BH1750 sensor validation process is carried out for zone 1, zone 2, and zone 3 using a lux meter, the goal is to measure light intensity accurately. The data collection process starts at 12.00 to 15.00 every 10 minutes of measurement. The location for data collection was in the classroom of the Department of Instrumentation Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia with an area of 50 m^2. Each validation process is shown in Figures 6-8 for each zone.

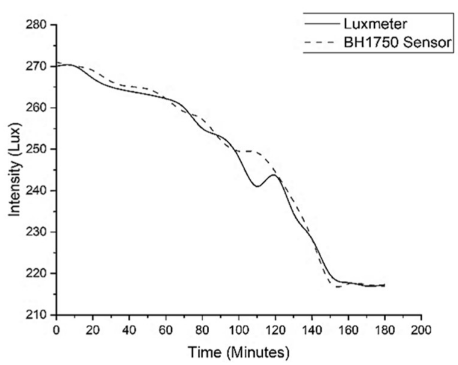

Figure 6. Validation of BH1750 sensor in zone 1

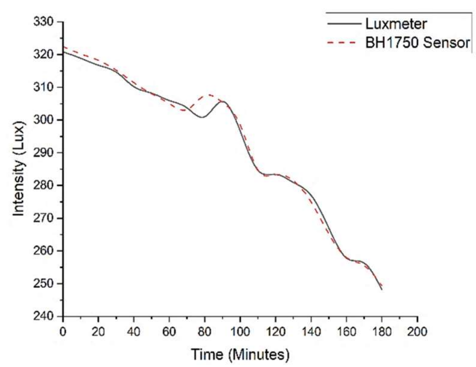

Figure 7. Validation of BH1750 sensor in zone 2

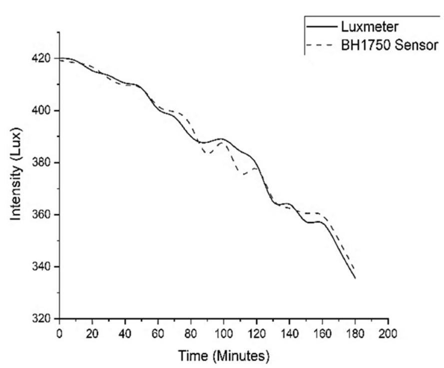

Figure 8. Validation of BH1750 sensor in zone 3

Error and measurement accuracy for the three graphs above are 0.1% and 99.9% respectively. These results indicate that the BH1750 sensor used can read the light intensity properly. In zone 1 the light intensity measured at 12.00 is 270 lux, in zone 2 is 320 lux and in zone 3 is 420 lux. Zone 3 has the highest lux reading due to the position close to the window so that the light intensity is high compared to zone 1 and zone 2.

As time goes by, the data collection at 15.00 shows that there is a decrease in light intensity where zone 1 reads 220 lux, zone 2 is 250 lux and zone 3 is 340 lux. This decrease is caused by the effect of reduced sunlight intensity. In zone 3, at exactly 12.00 it is necessary to reduce the light intensity according to the classroom standard, namely to 300 lux. At that time the dimmer actuator will work to reduce the intensity of the lamp by 120 lux so that the light intensity of the room becomes 300 lux. This also applies to all zones, if each zone has a light intensity above 300 lux, the dimmer will reduce it, whereas if the light intensity is below 300, the dimmer actuator will illuminate the light until the 300 lux set point is reached.

3.3. Energy saving calculation

Calculation of energy saving is carried out in zone 3, this zone was chosen because it has a light intensity value above 300 lux from 12.00 to 15.00. This energy saving calculation begins by calculating the power consumption spent using the power consumption equation in the reference [21]. The represented data was given in Table 1.

Table 1. Energy saving in zone 3 (close to the window)

Time (Minutes)	Set point intensity (Lux)	Set point power (Watt)	Light intensity (Lux)	Power (Watt)	Difference in light intensity (Lux)	Power saving (Watt)	Power saving percentage (%)
0	300	166	419.22	232.9	119.22	66.9	29
10	300	166	418.32	232.4	118.32	66.4	29
20	300	166	416.67	231.5	116.67	65.5	28
30	300	166	412.34	229.1	112.34	63.1	28
40	300	166	409.7	227.6	109.7	61.6	27
50	300	166	408.5	226.9	108.5	60.9	27
60	300	166	401.65	223.1	101.65	57.1	26
70	300	166	399.56	221.9	99.56	55.9	25
80	300	166	394.17	218.9	94.17	52.9	24
90	300	166	38.4	213	83.4	47	22
100	300	166	387.4	215.2	87.4	49.2	23
110	300	166	376	208.8	76	42.8	20
120	300	166	377.5	209.7	77.5	43.7	21
130	300	166	366	203.3	66	37.3	18
140	300	166	362.5	201.4	62.5	35.4	18
150	300	166	360.5	200.3	60.5	34.3	17
160	300	166	359.7	199.8	59.7	33.8	17
170	300	166	350.2	194.5	50.2	28.5	15
180	300	166	338.4	188	38.4	22	12

The average of decrease of the power consumption in zone 3 is 48.6 watts or 22%. This energy saving presentation is still better than the reference [21] for one classroom with a saving of 13.22%. We also calculate the average energy saving for 3 hours a day is 145.9 Wh and for 20 days a month we have the energy saving is 2.92 kWh. Our calculation for the energy saving a day, a month and a year based on the light intensity in Indonesia relatively constant during month and year [27]. Finally, we have the energy saving for a year is 35 kWh and can save money around 60,000 IDR (1 kWh=1,699.53 IDR) or 4 USD (1 USD=15,000 IDR).

4. CONCLUSION

A lighting automation system has been designed in a classroom with standard lighting of 300 lux. Measurements were made in 3 different zones, namely zone 1 far from the window, zone 2 in the middle of the room, and zone 3 closest to the window. Calculation of energy savings is carried out in zone 3 because it has an intensity value above 300 lux so that savings need to be made. The calculation results show that the average energy saving for using lights for 3 hours (12.00-15.00) is 2.92 kWh for 20 days for 1 month or 35 kWh per year or equivalent to saving money of 4 USD.

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