Web-based smart LED for saving energy consumption

F Al-Maghribi, I Al Fayyedh, K A Hernandi, R Nugraha, Estananto and M Abdurohman

1 School of Electrical Engineering, Telkom University, Indonesia
2 School of Computing, Telkom University, Indonesia

E-mail: alfayyedh@student.telkomuniversity.ac.id

Abstract. The lighting system takes a dominant part in the building. However, its use is still inefficient because the light provided by the lamp exceeds its needs and often the light stays on when it is not needed. It can be done by creating a lighting system that provide appropriate light for saving the use of energy. A smart lighting system is designed to control light intensity by using a device that is able to detect light intensity and movement. The lighting system will turn on when there is activity in the room, then the system will adjust the intensity in the room. Also, the energy consumption will be saved in the database to ease monitoring process. By using this system, working room’s light intensity will be maintained at standard light intensity value. And also, this system will save power consumption 50.7%.

1. Introduction

Nowadays, smart building is needed for some reasons, one of them is to save energy and it should be able to monitor the environment and to sense actions performed by inhabitants [1]. Some driver models that can control LED have been developed [2] and LED are used in smart lighting using IoT [3]. Luminaire monitoring has also been used for controlling the LED [4] and especially Daylight-based lighting controller on LED luminaire has also been developed [5]. Machine Learning has also been used extensively for smart building purposes [6] and a model based on Machine-to-Machine (M2M) platforms has also been built [7].

According to PLN statistic report on 2017, amount of electricity energy was raising for 3.30% than last year [8]. The increase obviously had effect to the electricity power resources and more fossil fuel is needed. Therefore, it may cause global warming. Additionally, lighting system consumes about 30% of total energy in a building [9]. According to [10], the light intensity standard for a workspace is 200lux, whereas in a storage room it is 100lux. So, a system that can control the intensity of light in the room is required.

Thus, the system will be designed as a device that has a light intensity sensor that is able to read the intensity of light in the room as well as a motion sensor that can read movement in the surrounding environment. This tool is also equipped with a current sensor that will calculate the amount of electricity consumed. Also, this tool will be connected to the server and database. The data that will be stored is the amount of energy consumption. The data will be displayed on a website to make it easier to be monitored. By using this device, the intensity of the light in the workspace will be maintained in the range of 180-120lux to obtain the energy saving by at least 10%.
1.1. Analytical model

1.1.1. Fuzzy logic controller. In 1974, Ebrahim Mamdani applied this fuzzy theory to the field of control known as the Fuzzy Control System or FLC (Fuzzy Logic Controller) [11]. FLC works based on fuzzy set and fuzzy set operation. Fuzzy set represents the linguistic value of a variable, for example the temperature variable is expressed by the linguistic value of hot, cool and cold. There are three processes that will be carried out in making decisions using FLC, including fuzzyfication, inference and defuzzyfication.

One of the FLC methods that is often used is the Sugeno method. This method was introduced by Takagi-Sugeno Kang in 1985. The system output in this method is not a fuzzy set, but a constant or linear equation. In general, the system output can be calculated by equation 1.

$$Output = \frac{\mu_{1} \cdot z_{1} + \ldots + \mu_{n} \cdot z_{n}}{\mu_{1} + \ldots + \mu_{n}}$$ (1)

1.1.2. HyperText transfer protocol. HyperText Transfer Protocol (HTTP) is an application layer developed to assist the process of data communication between computers [12]. The use of http is often done for communication between computers clients and web servers. HTTP is a protocol that allow the request-answer process between client and server. The HTTP protocol will open a connection to the web server to send HTML, JSON, pdf files and so on through the Uniform Resource Locator (URL).

1.1.3. Quality of service. Quality of Service is a measurement method that is used to identify how good the network, the character and the behaviour of networking service. The purpose of QoS is to give the better service and planning in order to fulfil the standard requirement.

1.1.4. Simple moving average. Simple Moving Average is a method used to reduce noise that occurs in sensor readings to display data. The SMA method in this system is built by entering the value of the sensor reading into an array of n numbers. The amount of data that enters the array is then divided by the value of n or the number of arrays. When the array is fully loaded, the leading array will shift out of the array and be replaced with new values that enter the array. The equation is as follows.

$$SMA = \frac{A1 + A2 + A3 + \ldots + An}{n}$$ (2)

When a new value is entered, the value A1 will be shifted by the value A2, A2 will be shifted by A3 and so on, so this method is called Simple Moving Average. By averaging the value of the sensor reading periodically, the noise that occurs when the reading will be reduced and will adjust to the average value while the SMA method is running.

2. Methods

In this research, the lighting system is designed to be able to produce light according to the light intensity determined using the FLC method. In this system there is a light sensor that will read the value of the light intensity in the room, a motion sensor that will detect movement around the room and a current sensor that will read the electric current that flows. This system will turn on when the motion sensor detects movement around the room and then the current sensor will read the current value. This value will be processed by the microcontroller and produce the amount of energy consumption. The light intensity sensor will read the light intensity in the room. Microcontroller will process the value read by the light intensity sensor and will give the output according to the programmed conditions. This system works by reducing the system error to the set point that aims to make the system works in the desired conditions. There are two control conditions, namely when the amount of energy consumption is below the average of normal amount of energy consumption and above the average of normal amount of energy consumption. The system block diagram can be seen in figure 2.
Figure 1. Flowchart of the systems.
The system on the node uses a 220 VAC source which will be converted to 24 VDC and 5 VDC. The output of the 24 VDC converter is used to provide a supply for the lamp connected via a dimmer module, while the 5 VDC converter is used to provide a supply for the microcontroller and sensor. The node will be connected to an access point/router that is connected to the internet network.

The node will give instruction to the server to store data in the database. The node will also ask the server to check the last command stored by the client in the database. This command will later be sent through the internet network, access point/router and processed by a microcontroller that has built in WiFi. There are three modes to choose from, there are the ON mode, the AUTO mode and the OFF mode. In the ON mode, the lamp will remain in active condition with maximum intensity. While in the OFF mode, the lamp will stay off and in the AUTO mode, the lamp will be controlled by the system so that the light intensity can be controlled. The microcontroller of this system has 10-bit DAC (Digital to Analog Converter) which means the microcontroller can drive PWM value from 0 to 1023 to control the dimmer module. The system workflow can be seen in figure 1.

3. Results and Discussion
The results obtained from studies conducted at the initial intensity conditions of the room in figure 3.
Figure 3 shows the greater the initial light intensity of the room, the smaller the PWM value needed by the system. This happens because when the initial intensity of the room has a quite large value, the system does not need to turn on the lights with great intensity but only needs to cover the lack of light intensity in the room.

![Figure 4](image)

**Figure 4.** Time of 5 Different Initial Light Intensity to Reach Maximum Light Intensity.

Figure 4 shows the greater initial light intensity of the room, the less time needed by the system. This happens because the PWM value needed is becoming smaller when the initial light intensity is big enough. The time needed for the system to reach that value is also faster.

![Figure 5](image)

**Figure 5.** Light intensity produced by the system of 5 different initial light intensity.

Figure 5 shows the greater the initial light intensity of the room, the intensity of the light produced by the system will be smaller. This happens because the greater the initial light intensity of the room, the set point value needed in the system is also getting bigger. So, by using a predetermined set point value (56lux), the intensity of lamp that can be generated by the system will decrease. However, there are exceptions to the initial intensity of 200lux because at that initial intensity, the lamp in the system are off and the intensity of the light that is read only comes from other light sources.
Figure 6. Light intensity produced by the system at 152-198 lux of initial light intensity.

Figure 6 shows the system’s performance decreased by the increasing of room intensity. The light intensity produced by the system runs below the minimum border and keep decreasing until the value of 172 lux room intensity. At this point, the system is no more activating the LED because error value that is counted by the system reached the minimum error. It can be solved by using additional light intensity sensor to compare the light intensity that is coming from other light sources.

Figure 7. Comparison between Power Analyzer and ACS712 reading.

Figure 7 shows the power analyzer and ACS712 readings. There is little in the curve, with an accuracy reading of kWh ACS712 is 94.75%. The Power Analyzer reading in the 30th data is 0.141 kWh and the ACS712 reading in the 30th data is 0.137 kWh.
Figure 8. Power comparison when set point change.

Figure 8 shows when energy consumption exceeds the maximum daily energy consumption limit, the set point will change from 56 lux to 53 lux, resulting in a power savings of 5.62% based on ACS712 and 6% based on the power analyzer.

Figure 9. Comparison between using the system and not using system.

Figure 9 shows the comparison between the lighting that is using the smart LED system (variation 2) and not using the smart LED system (variation 1). By using the smart LED system, energy consumption in 300 minutes is 0.137 kWh, while by not using the smart LED system, energy consumption in 300 minutes is 0.247 kWh. It means the smart LED system could save up to 50.7% of energy consumption.

4. Conclusion

The study conducted could be a solution for solving the excessive use of electricity issue, especially from lighting system. It is not only saving the energy consumption, but also can be used to make lighting system match the standardization. Without using the system, the energy consumed for 300 minutes is 0.247 kWh. Whereas when using the system, the energy consumed for 300 minutes is 0.137 kWh. Thus, the application of the system saves energy for about 50.7%. And by decreasing the set point when the normal consumption is exceeded, the the smart LED system could save 6% power consumption.
References

[1] Batov E I 2015 The distinctive features of smart buildings *Procedia Engineering* **111** 103– 107

[2] Yadlapalli R T, Narasipuram R P and Kotapati A 2019 An overview of energy efficient solidstate LED driver topologies *Int J Energy Res* **1**–**19**

[3] Higuera J, Llenas A and Carreras J 2018 *Trends in smart lighting for the Internet of Things* arXiv:1809.00986

[4] Pandharipande A and Caicedo D 2015 Smart indoor lighting systems with luminaire-based sensing: A review of lighting control approaches *Energy and Buildings* **104** 369–377

[5] Bunjongjit S, Ananwattanaporn S, Ngaopitakkul A, Jettanasen C and Patcharoen T 2010 Design and application of daylight-based lighting controller on LED luminaire *Appl Sci* **10**(10) 3415

[6] Qolomany B, Al-Fuqaha A, Gupta A, Benhaddou D, Alwajidi S, Qadir J and Fong A C 2019 Leveraging machine learning and big data for smart buildings: a comprehensive survey *IEEE Access* **7** 90316-90356

[7] Abdurohman M, Putrada A G, Prabowo S, Wijutomo C W and Elmagoush A 2018 Integrated lighting enabler system using m2m platforms *J. Inf. Process Syst.* **14**(4) 1033-1048

[8] PLN Corporate Secretary 2017 PLN Statistics 2017 **104** 2018.

[9] Amin N 2011 Lighting system optimization using natural lighting (case study: UNTAD electronics and microprocessor laboratora *J. Ilm. Foristek* **1**(1) 43–50

[10] Ministry of Health of the Republic of Indonesia 2017 Peraturan Menteri Kesehatan Republik Indonesia Nomor 70 Tahun 2016 Tentang Standar dan Persyaratan Kesehatan Lingkungan Kerja Industri

[11] Kusumadewi S and Purnomo H 2011 *Fuzzy Logic Applications for Supporting Decision Making Process* 2nd Ed (Yogyakarta: Graha Ilmu)

[12] Rombe A N, Aksara L M and Surimi L 2019 Analisis perbandingan real time streaming protocol (RTSP) dan hypertext transfer protocol (HTTP) pada layanan live video streaming *semantIK* **5**(1) 149-156

[13] Putranta F S 2017 *Designing and Analysis of Smart Lighting Based on Wireless Sensor Network for Enhancing Daily Activities at Home* (Bandung: Telkom University)

Acknowledgements
The authors are very grateful to the ministry of Research and Technology of the Republic of Indonesia for research funding under RISPRO scheme year 2019/2020 for this research.