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Design Lighting System Based on PID Control and Node-red

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ABSTRACT

In general, lighting systems use the on/off principle, by turning on the lights in a dark room and turning off the lights in a bright room. This has drawbacks in terms of effectiveness, because it does not pay attention to external influences and lighting, namely sunlight. To overcome this problem, automatic light intensity control is needed which still refers to the surrounding lighting. The aim of this research is to understand the performance of light intensity control devices in lighting systems using the PID method. Comparing the measurements of the BH1750 sensor with a lux meter measuring instrument, an average error value of 6.61% was obtained. Searching for PID parameters uses the trial and errors method with 5 attempts on each parameter. In testing each parameter, optimal results were obtained for the PID parameters, namely Kp = 0.10 Ki = 0.18 Kd = 0.10 with a system response value of 7.91, settling time of 14.63 and overshoot of 0.97.

1. INTRODUCTION

Lighting is a comfort factor in carrying out an activity indoors. The decline in human performance in the room is one of them caused by less than optimal lighting. Light is small and light particles that move quickly without the need for a medium, while what is meant by lighting is the irradiation used to facilitate an activity to run effectively and efficiently[1][2]. Lighting is one of the comfort factors in doing indoor activities. Good lighting can increase human productivity in carrying out activities Usually the lighting system will turn on the lights when the light is dark and turn off the lights when the light is bright [3][4]. This type of housing has a disadvantage in terms of efficiency because it does not take into account external influences and lighting, especially sunlight [5][6][7].

Controlling electrical devices such as lights is important for processing electrical energy in a place that has many lights. Waste of electrical energy often occurs in a room due to forgetting to turn off the lights which can result in inefficient use of electrical energy [8][9][10]. Science and technology have now developed so rapidly that it makes it easier for someone to do work. In general, there are two types of control systems, namely automatic control systems and manual control systems [11][12][13]. An automatic control system is a system controlled by a device configured to operate automatically. A manual control system is a system that is controlled by humans [14][15][16].

In an automatic control system there are several controls, namely proportional control (P), integral control (I), and Derivative control [17][18][19]. Each of these controls has its own advantages. Proportional control has the advantage of increasing time or overshoot, stabilizing the system response, and can reduce or decrease the steady state error value [20][21][22][23]. Integral control has the advantage of minimizing errors that occur in a plant, reducing the rise time value but will have the effect of increasing the overshoot value, and can increase stability in a plant [24][25]. Derivative control has a role or function to minimize the lack or excess of system response responses in a plant, reduce the overshoot value of the plant, reduce the level of stability in the plant, and can provide small changes in the value of the steady state error [26][27]. To get a good control system, have a fast time increase and have a good level of stability, can be obtained by combining the three controls, namely proportional control, integral control and derivative control [28][29][30][31]. This study propose a PID control tool on a node-red based lighting system. This system is made with several electronic

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components, namely ESP32, BH1750 sensor, AC light dimmer, real time clock, PZEM 004t sensor and can be controlled using Iot (Internet of Things) technology using node-red platform.

2. METHOD

Lighting is a comfort factor in doing an activity indoors. Good lighting can increase human productivity in carrying out an activity. There are 2 types of lighting, namely natural lighting and artificial lighting. The advantage of natural lighting is that it can save electrical energy. Artificial lighting is created through the use of electrical energy that is converted into light. This artificial lighting has disadvantages if not used efficiently will cause waste of energy.

2.1. PID Controler

PID controller is a mechanism controller using a feedback system which usually uses a sensor as feedback. PID controllers are usually used in industrial control systems. In the PID controller there are 3 variables or parameters, namely proportional, integral, and derifatife. The block diagram of the PID controller can be seen in Figure 1. Each parameter has a different influence on the response results. The following is an explanation of the effect of each parameter [32][33][34][35].

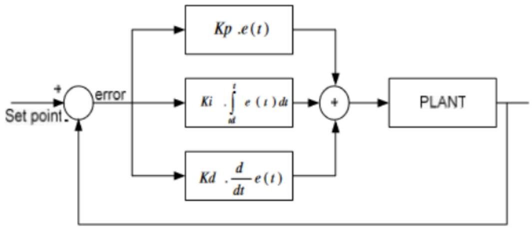

Figure 1. PID Control

This proportional controller is obtained from the result of multiplying the proportional constant with the error value. This proportional controller is obtained from the result of multiplying the proportional constant with the error value. Derivative controllers affect the damping of a system so as to minimize spikes. This controller also cannot eliminate offsets like proportional control.

2.2 Node-red

Node-red is a browser-based tool for building web of Things (IoT) applications where a visual programming environment facilitates user activity "streams" for creating applications. These streams consist of interconnected nodes in which each node performs a specific task. Although Node-RED has been created for Internet of Things (IoT), it can also be used for general purpose and various applications [36][37][38][39].

2.3 ESP32

ESP 32 is a microcontroller introduced by esprensif system, which is the successor of ESP8266 microcontroller. This microcontroller has built-in WiFi and Bluetooth modules making it very useful for creating IoT (Internet of Things) application systems. Key Features of ESP32 Supports Wi-Fi and Bluetooth (BLE and Classic), allowing the device to connect to the internet or other Bluetooth devices. ESP32 has a dual-core processor (Xtensa LX6) running at up to 240 MHz, making it suitable for applications that require fast processing. ESP32 provides many Input/Output (GPIO) pins that support various communication protocols such as I2C, SPI, UART, PWM, and ADC/DAC. ESP32 is equipped with a low power mode that makes it ideal for applications that require energy efficiency, such as battery-powered IoT devices [40][41][42][43].

2.4 PZEEM-004T

The PZEM-004T module is a versatile sensor module with a focus on measuring energy, voltage, current, and power. A voltage sensor and a current sensor are included with this module. The use of this tool is specific to the room (indoor). This module has been wrapped with a transformer that can measure a maximum current of 100A. This module requires 5V external power [44] .

2.5 BH1750 Sensor

The BH1750 sensor is a sensor that functions to detect the intensity of ambient light which has an output in the form of a digital signal. This sensor is easier to use and more accurate when compared to sensors such as light dependent resistors (LDR) because the LDR sensor still requires calculations to determine the intensity of light and the signal output from the LDR sensor is still analog [45][46][47][48].

2.6 AC Light Dimmer

The AC Light Dimmer module is a dimmer module that can be controlled by Arduino. This module has a zero pin crossing detector that can determine the right time to send a PWM signal. This module has a function as a light regulator from a lamp that utilizes voltage as input using TRIAC .

2.7 Real Time Clock (RTC)

A Real Time Clock (RTC) can precisely calculate time in seconds to years and record and store this time information in real-time. An electronic clock known as a real time clock (RTC) can calculate the time precisely in seconds to years and record and store this time information in real-time. RTC chips are commonly found on PC motherboards RTCs are considered to be fairly accurate timers because they use DS323 Series crystal oscillators.

3. RESULTS AND DISCUSSION

3.1 Hardware Design

The research stages can be seen in Figure 2(a), Figure 2(b) is a PID block diagram, Figure 2(c) is a hardware circuit, Figure 2(d) is the final result of the tool. The microcontroller will process the data received in such a way using the PID method where the results will be sent to the AC Light Dimmer module so that it will adjust the light intensity according to the predetermined setpoint.

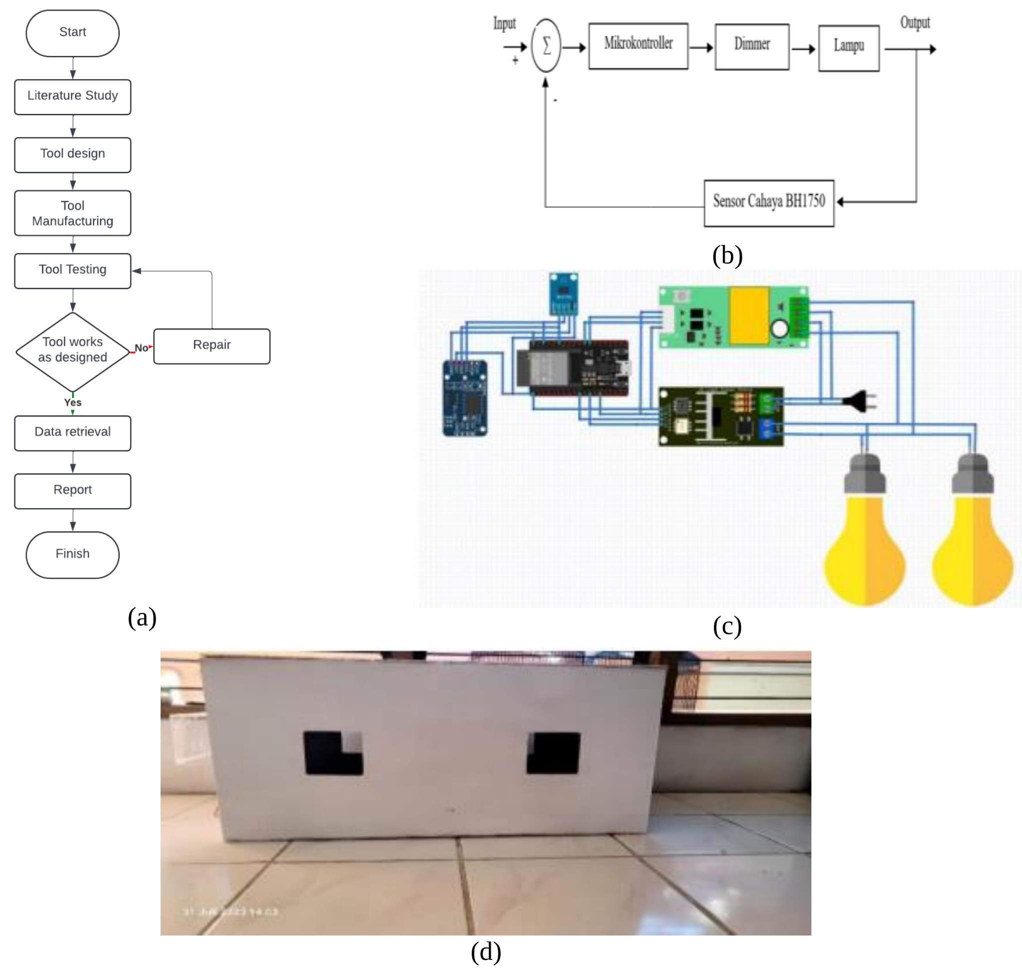

Figure 2. Hardware Designs: (a) Research stages, (b) PID Block diagram, (c) Hardware Circuit, (d) Final Results

3.2 Software Degign

Software planning in this study uses PID programming through the Arduino IDE application. Where the software reads the value of light intensity in the plant used as input through the BH1750 light sensor which will then be controlled using PID to regulate the intensity of light according to a predetermined setpoint. software flowchart can be seen in Figure 3.

3.3 Device and Sensor Testing

In this study, several tests were carried out, the first test was testing the BH1750 light sensor, the second test was determining the PID parameters, the third test was testing the PID interference against interference.

3.3.1 BH1750 Light Sensor Testing

The BH1750 sensor test aims to determine the accuracy of the sensor by using a lux meter measuring instrument as a comparison. Table 1 is the result of the sensor test.

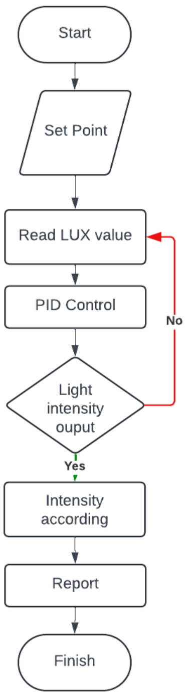

Figure 3. Flowchart software

Table 1. BH1750 Sensor testing

No.	Time	BH1750 Value (Lux)	Value of Measuring Instrument (Lux)	Error (%)
1	09:00	20	22	9
2	10:00	24	26	7.6
3	12:00	48	51	5.8
4	13:00	37	39	5.1
5	15:08	139	144	3.4
6	16:57	41	45	8.8
Average Error Value				6.61 %

The BH1750 sensor test results are obtained through the equation below.

$$E = \frac{(LMV - SV)}{LMV} X\ 100 \quad (1)$$

Where E is Error (%).$LMV$is Lux Meter Value. SV is Sensor Value. Meanwhile, to calculate the average error using the equation below.

$$\bar{x}E = \frac{\sum E}{\sum P} X\ 100 \quad (2)$$

.

Where $\bar{x}E$ is Average error (%).$\sum E$ is Number of error values. $\sum P$is Number of trials.

3.3.2 Determination of PID Parameters

In this research, the process of determining PID parameters uses the trial and error method. In this test, the PID parameters use 5 trials on each parameter which can be seen in the most optimal response results. In PID testing, the data that will be analyzed to find optimal parameters in the form of system responses, namely overshoot, rise time, and settling time.

3.3.3 K_p Parameter Testing

Based on the results of 5 trials of the K_p parameter, it can be concluded that the smaller the K_p value, the smaller the rise time will be but the settling time will be greater so that it will be faster for a plant to reach the setpoint to be determined. In the table, the parameter K_p = 0.1 has a faster response so that it is faster to reach the setpoint value In Table 2 is the result of 5 trials of the Kp parameter.

3.3.4 K_i Parameter Testing

Based on the results of the 5 K_i parameter experiments, it can be concluded that the greater the Ki value, the faster the rise time and settling time will be so that the faster a plant will reach the setpoint to be determined. It can be seen that the K_i = 0.18 parameter is faster in response to reach the setpoint than K_i = 0.1. Table 3 is the result of 5 trials of the K_i parameter.

Table 2. K_p Parameter testing results

	PID Parameter			**Rise Time (S)**	**Settling Time (s)**	**Over shoot (%)**
	K_p	K_i	K_d			
Set point (120 Lux)	0.1	0.1	0.1	15.69	45.35	1.39
	0.12	0.1	0.1	17.65	40.14	1.73
	0.14	0.1	0.1	18.93	44.19	1.66
	0.16	0.1	0.1	19.55	43.92	0.55
	0.18	0.1	0.1	20.06	39.64	0.62

Table 3. K_i Parameter testing results

	PID Parameter			**Rise Time (S)**	**Settling Time (s)**	**Over shoot (%)**
	K_p	K_i	K_d			
Set point (120 Lux)	0.1	0.1	0.1	15.65	45.35	1.39
	0.1	0.12	0.1	13.4	32.2	1.25
	0.1	0.14	0.1	11.24	100.53	7.08
	0.1	0.16	0.1	8.56	16.73	1.1
	0.1	0.18	0.1	7.28	13.9	1.1

3.3.5 K_d Parameter Testing

Based on the results of 5 trials of the K_d parameter. it can be concluded that the greater the K_d value. the faster the rise time and settling time will be so that the faster a plant will reach the setpoint to be determined. It can be seen in the table below that the parameter K_d = 0.18 is the faster the system response reaches the set point compared to the parameter K_d = 0.1 In Table 4 is the result of 5 times the Kd parameter experiment.

3.3.6 Optimal PID Response Results

From the results of determining PID parameters by trial and error. optimal PID parameter data can be taken by combining or combining PID parameters. The optimal PID parameters based on the results of trial and error are K_p = 0.10 K_i = 0.10 K_d = 0.10. With a rise time of 7.91. settling time of 14.63 and overshoot of 0.97 The response results of these parameters can be seen in Table 5.

Table 4. Kd Parameter experiments

	PID Parameter			**Rise Time (S)**	**Settling Time (s)**	**Over shoot (%)**
	K_p	K_i	K_d			
Set point (120 Lux)	0.1	0.1	0.1	15.65	45.35	1.39
	0.1	0.1	0.12	14.85	27.19	0.9
	0.1	0.1	0.14	14.57	31.57	1.45
	0.1	0.1	0.16	13.61	41.57	1.66
	0.1	0.1	0.18	13.71	29.11	1.66

Table 5. Optimal response testing result

Set point (120 Lux)	PID Parameter			Rise Time (S)	Settling Time (s)	Over shoot (%)
	K_p	K_i	K_d			
	0.10	0.18	0.10	7.91	14.63	0.97

3.3.7 PID testing against disturbance

In this test. the system was given a disturbance in the form of a lamp light. The system was disturbed at 42 seconds. The response graph experienced instability so that the system response experienced an increase in light intensity of 151 Lux. the plant is not given a disturbance the controller can return to following the predetermined setpoint without any effect. The response graph is seen in Figure 4.

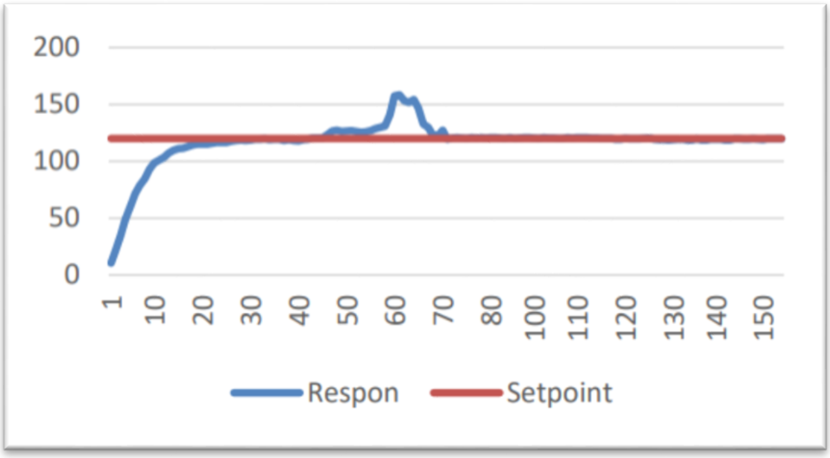

Figure 4. Testing graph against disturbance

4. CONCLUSION AND LIMITATION

Based on the results of the research that has been done. It can be concluded that the PID control design on the lighting system was successfully made using the PID method with the search for PID parameters using the trial and errors method by testing each optimal parameter. The test results obtained optimal parameters with a setpoint of 120 lux. Namely K_p= 0.1 K_i = 0.1 and K_d = 0.18 with a system response value of rise time 7.91 (s) settling time 14.63 (s) and overshoot 0.97%. In the process of testing the system is disturbed for 10 seconds the light intensity increases by 151 lux after the system is not disturbed the controller can return to the setpoint. Based on the research that has been done. There are several things that have been developed to achieve the best results. I.e. Using other control methods such as fuzzy logic or combining 2 controllers such as fuzzy PID and others. Using auto tunning to find better PID parameters.

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