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Monitoring System and Temperature Controlling on PID Based Poultry Hatching Incubator

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Abstract. Poultry hatching cultivation is essential to be observed in terms of temperature stability by using artificial penetration incubator which applies On/Off control. The On/Off control produces relatively long response time to reach steady-state conditions. Moreover, how the system works makes the component worn out because the lamp is on-off periodically. Besides, the cultivation in the market is less suitable to be used in an environment which has fluctuating temperature because it may influence plant's temperature stability. The study aims to design automatic poultry hatching cultivation that can repair the temperature's response of plant incubator to keep stable and in line with the intended set-point temperature value by using PID controller. The method used in PID controlling is designed to identify plant using ARX (Auto Regressive eXogenous) MATLAB which is dynamic/non-linear to obtain mathematical model and PID constants value that is appropriate to system. The hardware design for PID-based egg incubator uses Arduino Uno R3, as the main controller that includes PID source, and PWM, to keep plant temperature stability, which is integrated with incandescent light actuators and sensors where DHTI 1 sensor as the reader as temperature condition and plant humidity. The result of the study showed that PID constants value of each plant is different. For parallel 15 Watt plant, Kp = 3.9956, Ki = 0.361, Kd = 0, while for parallel 25 Watt plant, the value of Kp = 5.714, Ki = 0.351, Kd = 0. The PID constants value were capable to produce stable system response which is based on set-point with steady state error's value is around 5%, that is 2.7%. With hatching percentage of 70-80%, the hatching process is successful in air-conditioned environment (changeable).

1. Introduction

In daily life, human being's activities require stable temperature both for their comfort in their activities and for their work as in poultry farms. Poultry hatching cultivation has to be heeded in terms of successful process, even more for local chicken eggs. Hatching eggs has two ways; 1) incubated by the chicken hen directly and 2) through egg hatching machine with a system to control the temperature of the radiation of heating lamp. According to the field survey on egg hatcher, the result showed that: 1) the suitable temperature of incubation is at 37 ° C; 2) the span of the egg-laying period is approximately 21 days; 3) and the characteristics of incubator's design and egg. Stability of hatchery room temperature should always be maintained in order to obtain maximum results (Angga, 2016)

Fluctuation in environmental temperatures can influence the temperature of the hatchery (*forced air*). Moreover, the working system is still On / Off with the outages of the heating lamp which cause wear-worn components. Besides, while the system is still not precise, there is a big error which has a relatively long settling time to reach the next set point due to the instability of the radiation beam temperature. Therefore, an idea to control the temperature of the incubator appears in order to reduce error level, wear out on components and keep the system working so that the temperature is more stable (steady state) based on the set point with PID control method. This method can be used to determine each parameter which is done by plant identification process to get mathematical model through ARX (Auto Regressive eXogenous).

This study used Arduino Uno R3, DHT11 sensor and lamp driver as PWM driver (Pulse Width Modulation) incandescent lamp 15 Watt / 25 Watt Parallel and fan driver for DC 12 Volt fan switch. In addition, it is to monitoring the temperature graph in the system using GUI MATLAB. This egg incubator uses a manual egg-activator every 6 hour which aims to prevent embryo hatching when attached to the eggshell. The research problems include the realization of automatic egg incubator with PID control method so that the temperature in the system can be stable (steady state) in fluctuating environmental temperature for optimal quality and quantity of eggs.

2. Research Methodology

2.1. Research Approach
This study uses Arduino IDE and Matlab 2015a software for simulating and operating PID system that would be used and designing plant build which would produce temperature response in egg hatching incubator.

2.2. Research Setting and Time
The research was carried out in the Laboratory of Engineering Physics of the Department of Electrical Engineering of the State University of Surabaya and its execution time was done in the even semester of 2016/2017.

2.3. Research Design
The design of this study aims to answer the problem in order to formulate the conclusion, as described in Figure 1. Flow diagram as follows:

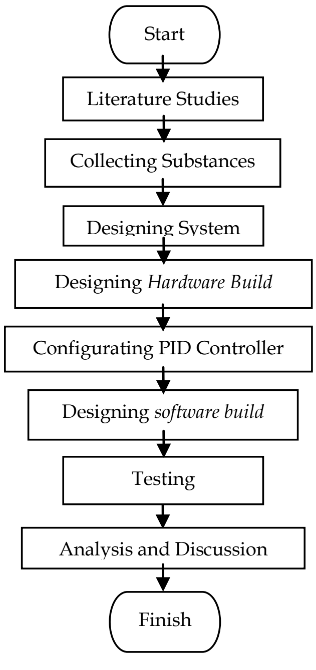


Figure 1. Flow Diagram of Research Stages

2.4. Designing Hardware Build
The design of hardware build includes several block designs namely; power supply block, sensor block, lamp driver block, fan driver block, LCD block, and egg incubator plant block.

2.5. Power Supply Block
Power Supply (Power Supply) on this system has an important role as a source of DC voltage on the system. With PLN input voltage mesh as input, Power Supply has two outputs which each of them has 9 Volt and 12

Volt output. Voltage of 9 Volt is used for Arduino Uno R3 while the voltage of 12 Volt is for fan driver supply needs. Figure 2 is schematic of power supply circuit.

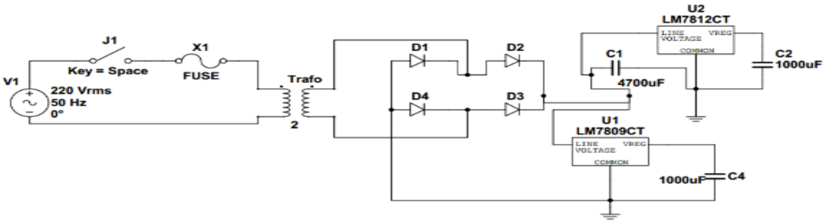


Figure 2. Power Supply

2.6. DHT11 Sensor Block

The DHT 11 sensor is a calibrated sensor with an accuracy level of ± 2 ° C and a humidity level of ± 5% RH which is connected to pin 2 of Arduino Uno with a 40 cm cable to be treated and processed as data input. Figure 3 is DHT11 sensor scheme.

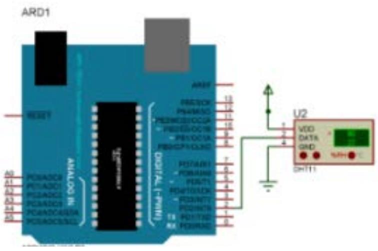


Figure 3. DHT11 Sensor

2.7. Lamps Drivers Block

The lamp driver has a principle to use a 220 Volt AC voltage input rectified through several *Wheatstone*-generated diodes that produce DC voltages with great power and current. There is an Optocoupler component as a switch interface with MOSFET. The lamp driver has a role as a PWM actuator that gets signal from Arduino. The following figure is a schematic of the lamp driver circuit.

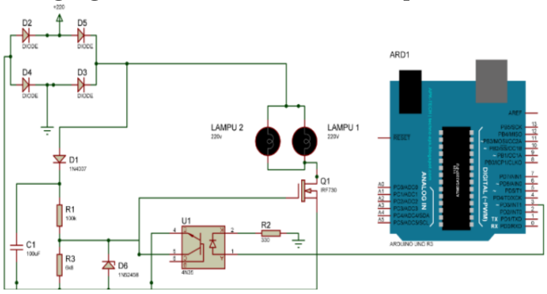


Figure 4. Lamps Driver

2.8. Fan Driver Block

This fan driver has a role to run the fan during the hatching process so that the temperature inside the incubator evenly and throw hot air when the temperature exceeds the *setpoint* value. Figure 5 is fan driver scheme.

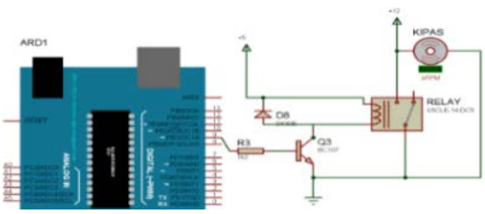


Figure 5. Fan Driver

2.9. 16X2 LCD Block

The LCD display is enabled to display the temperature and humidity values in the egg incubator. It uses I2C LCD module to minimize the number of cables connected to the Arduino pin. Figure 6 is 16X2 LCD Scheme.

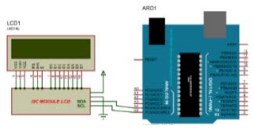


Figure 6. LCD Scheme 16X2

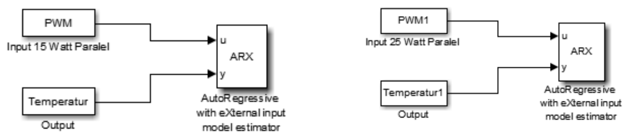
2.10. Egg Incubator Plant Block

This study used a plant made of wood, namely *Triplek*. This type of wood is ideally used as a raw material for incubator egg hatchery. The dimension of incubator is 30 x 40 x 32 cm with a height of 30 cm from the ground. Figure 7 is the design of an egg incubator plant incubator.

Figure 7. Egg Incubator Plant Design

3. Configuration of the PID Control

Before designing the PID control configuration which is appropriate to the plant, the first step is to design the whole system of the egg hatching incubator and then identify the system with ARX (AR-Auto Regressive X-eXogenous) method associated with the PWM stage input and output in the form of temperature that is measured to obtain a mathematical model of a dynamic system. The data object was created using Matlab system identification toolbox with Simulink ARX. Figure 8 is Simulink used for system identification for each plant.



(a) **(b)**

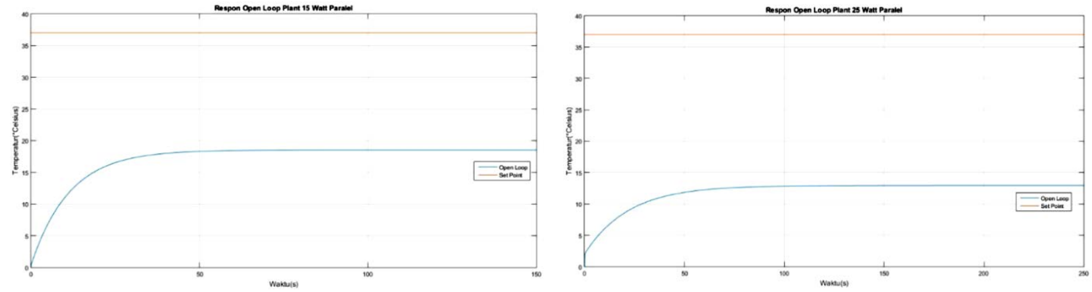
Figure 8. Simulink System Identification of (a)15 Watt Parallel Watts (b) 25 Watt Parallel

The result of transfer function obtained from Simulink is still a discrete transfer function. To get transfer function continuous (Laplace Transformation), it used sysc = d2c (sysd) syntax. Below is each Transfer Function continuous plant 15 Watt Parallel and 25 Watt Parallel:

$$\text{Plant 15 Watts} = \frac{0.496s+1.658}{s^2+37.6s+3.313}$$

$$\text{Plant 25 Watt} = \frac{1.711s+0.4965}{s^2+31.02s+1.419}$$

The testing of open loop response model of mathematical plant used step test signal with step 37 value according to the targeted temperature. Figure 14 and Figure 15 is open loop response result of each plant:



(a) **(b)**

Figure 9. Open Loop Plant Response of (a) 15 Watt Parallel (b) 25 Watt Parallel

The results of Fig. 9 are characteristic of first order system response graphs. The steady state output value of each system still has not reached the 37 setpoint value of 18.52 ° C for the 15 Watt and 12.95 ° C for 25 Watt plants. Therefore, a PID control is required with the first order method to achieve the targeted steady state value. With the method of first order system approach, it is determined of the value of $\tau = \tau i$ to determine the value of Kp, Ki, Kd.

4. Designing Software Build

Software in this study used IDE Arduino 1.6.12 and Matlab 2015a. The design of the program used for the PID eggs hatching system begins by creating a flowchart program. The whole flowchart program can be seen in Figure 10.

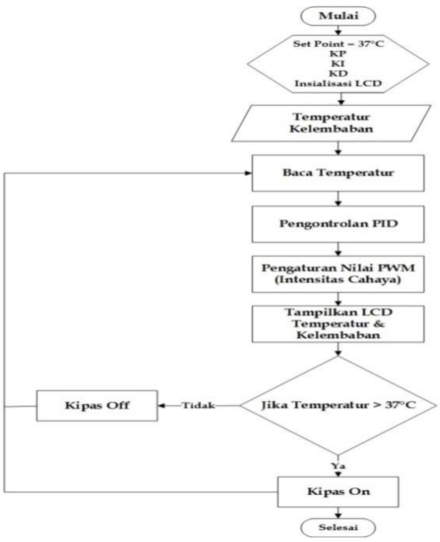


Figure 10. Flowchart Program System

5. Results and Discussion

Testing and research analysis include; 1) analysis and testing of plant control system circuit design for PID, 2) application of PID control configuration on plant, 3) PID control test result.

5.1. Testing of circuit design

The test circuit design includes power supply, DHT11 sensor, light driver, and fan driver. Below is each block of circuit testing:

6.1.1 Power supply. Power Supply (Power Supply) on this system has an important role as a source of DC voltage on the system. Based on Power Supply input measurement of 224.6 Volt AC, for output 1, the voltage is 9.06 Volts as the Arduino source, while the output voltage 2 is 12.20 Volts as the DC fan source.
DHT11 Sensor

In this research, this thesis compares DHT 11 temperature reading data with other temperature instrumentation which has ± 3% temperature accuracy level with 1 ° C resolution, that are Clamp Meter and Digital Thermometer with accuracy of ± 1 ° C. Testing by comparing the readings of other types of temperature sensors aims to see the accuracy of DHT11 sensors. The following table is Comparison of sensor accuracy:

Table 1. DHT Sensor Test 11 and Clamp Meter

No.	Time	DHT 11 Sensor		Clamp Meter	Difference
		°C	%RH	°C	°C
1.	Morning (07.00-08.00)	22	61	24	2
2.	Afternoon (13.00-14.00)	24	54	26	2
3.	Night (22.00-23.00)	21	62	22	1
				Average	1.7

Table 2. DHT Sensor 11 Testing and Digital Thermometer

No.	Time	DHT 11 Sensor		Digital Thermometer	Difference
		°C	%RH	°C	°C
1.	Morning (07.00-08.00)	22	61	25.3	3.3
2.	Afternoon (13.00-14.00)	24	54	27.9	3.9
3.	Night (22.00-23.00)	21	62	24.7	3.7
				Average	3.6

6.1.2 Lights Driver. This lights driver has a principle of PWM to supply voltage to the incandescent lamp. With the PWM 0-255 value indicator of the Arduino control that will provide the light level response. Calculation analysis of lamp driver component specifications:

Zener Diode component used is 15 Volt 1 Watt.

$$\mathrm{P} = \mathrm{Vzener.\,I} \tag{1}$$

$$\mathrm{I} = \frac{P}{Vzener} \tag{2}$$

$$\mathrm{I} = \frac{1}{15} = 0.07 \text{ A}$$

Voltage after the wheatstone bridge rectifier :

$$Vm = VAC\, x\, \sqrt{2} \tag{3}$$

$$Vm = 224.6 \text{ x } \sqrt{2} = 317.63 \text{ Volt}$$

$$VDC = \frac{2Vm}{\pi} \tag{4}$$

$$VDC = \frac{2\ X\ 317.63}{3.14} = 202.31 \text{ Volt}$$

The current flowing in R1

$$VR1 = Vm - Vzener \tag{5}$$

$$VR1 = 317.63 - 15 = 312.63 \text{ Volt}$$

$$IR1 = \frac{VR1}{R1}$$

$$IR1 = \frac{312.63}{100K} = 3.1263 \text{ mA}$$

The power produced is

$$P = V\, x\, I \tag{6}$$

$$P = 312.63\, x\, 3.126\, x\, 10^{-3} = 0.977 \text{ Watt} \approx 1 \text{ Watt}$$

So, for the use of R1 component is 100KΩ with 2 Watt power in order to be more secure. Specification diode zener Vzener 15 Volt, to get the value of R3:

$$R3 = \frac{\text{Vzener}}{IR1}$$

$$R3 = \frac{15}{3.1263} = 4.798 \approx\approx 4k7\ \Omega$$

So for the use of R3 component is 6K8 Ω with 1 Watt power in order to be more secure.

6.1.3 Fan Driver. This circuit works when there is an input signal with logic 1 of the Arduino that will activate the On condition transistor which makes the active relay from normally open to normally close. With the active relay normally close, the fan will be activated to a predetermined temperature limit. This fan driver will be Off when receiving input with logic 0 when the temperature is met which makes the transistor will be on Off position. Besides, the relay will be Off to the normally open position.

5.2. Application of PID Control Configuration

Based on the results of the open loop response, each plant indicates the response type including first order system characteristics because there is no Overshoot. So, the control method uses PI (Proportional Integral) controller with Kd = 0, τ = τi for optimum output response value suitable to input value.

For Parallel 15 Watt Plant:

$$K = \frac{Yss}{Xss} \tag{7}$$

$$K = \frac{18.52}{37} = 0.50054$$

$$\tau = 11{,}046 \text{ s accelerated 2x}$$

$$\tau^* = 5{,}523 \text{ s}$$

To get the value of Kp refers to equation (4).

$$Kp = \frac{\tau i}{K\tau *} = \frac{11.046}{0.50054x5.523} = 3.9956$$

$$K_i = \frac{K_p}{\tau_i} = \frac{3.9956}{11.046} = 0.361$$

Validation control of 15 Watt PI to know the response after controlled.

$$PI = Kp\ (1 + \frac{1}{\tau is})$$

$$PI = 3.9956\ (1 + \frac{1}{11.046}) = 4.357$$

For Parallel Plant 25 Watt:

$$K = \frac{12.95}{37} = 0.35$$

$$\tau = 18.1140 \text{ s accelerated 2x}$$

$$\tau * = 9{,}057 \text{ s}$$

To obtain the value of Kp refers to equation before.

$$Kp = \frac{\tau i}{K\tau *} = \frac{18.1140}{0.35x9.057} = 5.714$$

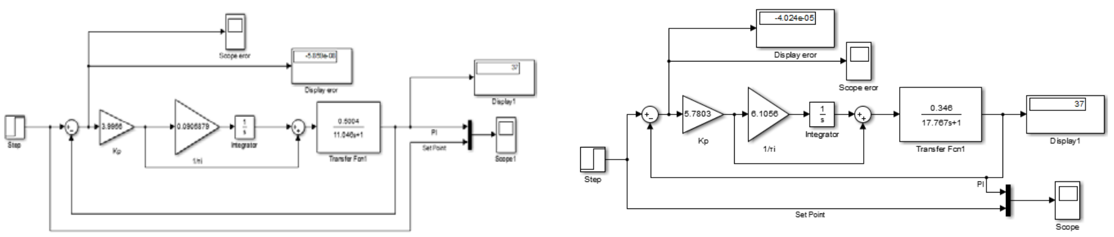
$$K_i = \frac{K_p}{\tau_i} = \frac{5.714}{18.1140} = 0.315$$

Validation of 25 Watt PI control to determine response after controlled.

$$PI = Kp\ (1 + \frac{1}{\tau is})$$

$$PI = 5.714\ (1 + \frac{1}{18.1140}) = 6.0294$$

Figure 17 and Figure 18 simulate of each plant using a PI controller.



(a) (b)

Figure 11. Simulation of PI Controller at (a)15 Watts Plant (b) 25 Watt Plant

Each plant has different value of PID constant to achieve a stable value. In the plant with 15 Watt parallel lamps have been identified the response system in accordance with first order system which it generally uses PID controller constant value Kp = 3.9956, Ki = 0.361, Kd = 0. While the plant with 25 Watt parallel lamps has been identified the response system constant value Kp = 5.714, Ki = 0.315, Kd = 0. After that, the PID value is implemented into the Arduino program. Testing of each plant with a PI controller results a temperature response that matches with the step setpoint input value of 37 ° C. Here are Figure 12 about Plant Response with PI controller.

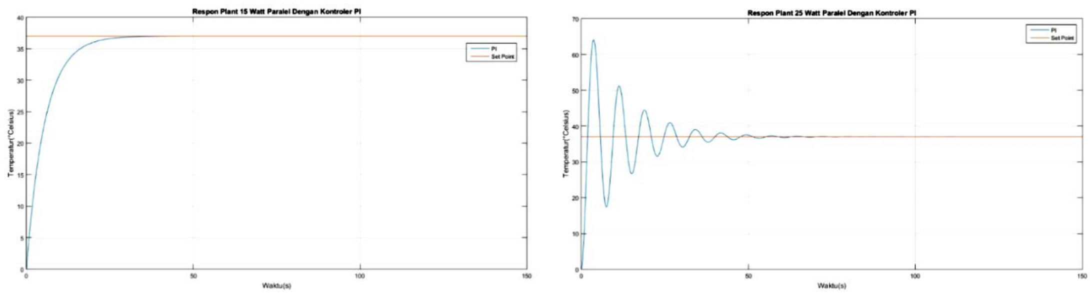


Figure 12. Plant Response with PI Controller of (a) 15 Watts (b) 25 Watt

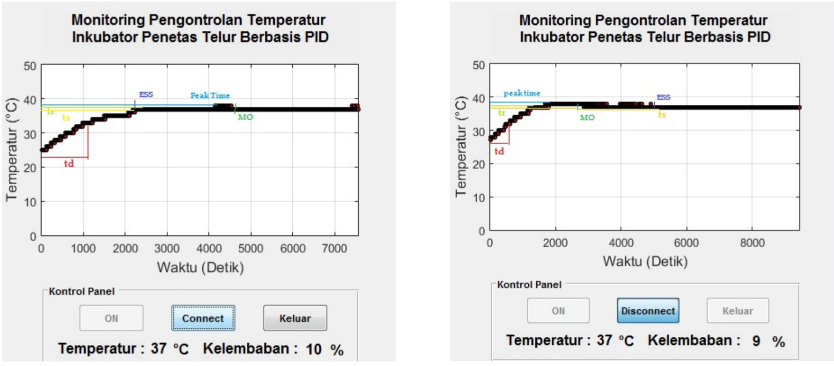
5.3. PID Control Test Result

6.3.1 Monitoring Plant Train Graph. In the process of monitoring, PID control train chart for each plant has different response according to the result of PID constant value which has been analyzed. The test is carried out with the initial temperature adjusting the ambient temperature to the system between 25-26 ° C by providing a *setpoint* value of 37 ° C.

For 15 Watt parallel plant in the egg incubator has a constant value of Kp = 3.9956, Ki = 0.361, Kd = 0 yields a rise time response of 2178 seconds to achieve the first steady state (settling time) and delay time of 1089 seconds. In this 15 Watt plant PID control test, it has a steady state error value of 0% which indicates successful control from 5% tolerance. In this test, the result showed that the result value of Overshoot Maximum 2.7% with peak value of 38 ° C. The time to reach the peak value of the response (peak time) is 4100 seconds.

The 25-watt parallel plant on the egg incubator has a constant value of Kp = 5.714, Ki = 0.351, Kd = 0 yielding a rise time of 1244 seconds to reach the first *setpoint* value and a delay time of 622 seconds. In this test, the result showed that the result value of Overshoot Maximum 2.7% with peak value of 38 ° C. The time to reach the peak value of the response (peak time) is 1740 seconds. To reach the steady-state value after the peak value has a settling time of 5010 seconds. In this case, 25 Watt plant PID control test has a steady state error value of 2.7% indicating successful control of 5% tolerance.

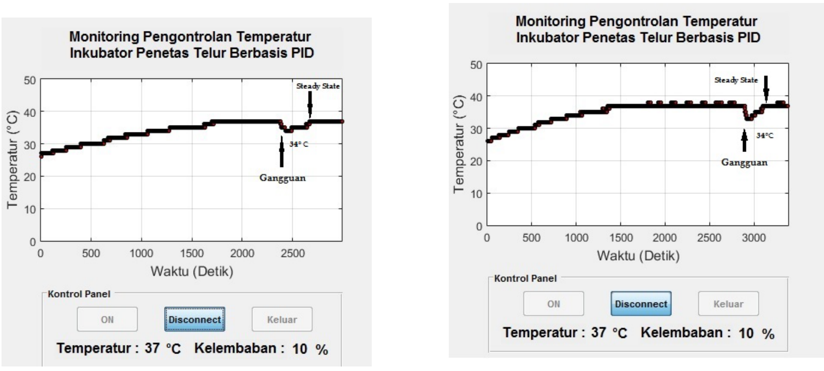
Figure 13 is the response graph analysis on a 15 Watt GUI plant display using PID controller.



(a) (b)

Figure 13. Graphic Response Analysis On (a) 15-Watt and (b) 25 watt GUI Display Plant Using PID Controller

Testing a 15 watts plant of interference is given at 2368 seconds. When the disruption is given by opening the incubator door for 20 seconds, the response graph indicates that the system is experiencing instability, the temperature drop 3°C from the *setpoint*. It takes a settling time of 215 seconds to reach the *setpoint* withstand steady-state conditions. This indicates good enough response system in responding to interference. Figure 14 is the graphical analysis of 15 Watt plant response to disturbance.



(a) (b)

Figure14. Graph Analysis of (a) 15 Watt and (b) 25 Watt Response Plant to Interference

While for the 25-watt plant is given interference at 2891 seconds. When disturbed by opening the incubator door for 20 seconds, the response graph is instability, the temperature drop to 3°C reaching 34°C. It takes 150 seconds of settling time to reach the *setpoint* value in the steady state. This indicates that the response of a 25-watt system plant reaches steady state faster than the response of a 15-watt plant system in responding to interference. Figure 24 is the analysis of 25 Watt plant response to the disturbance chart.

6.3.2 Hatching Results. Based on research that has been conducted on April 7 to May 2, 2017, the temperature stability treatment significantly affects the hatch results. Through stable temperature control, it has a faster temperature time level in terms of hatching. The result of a 15 Watt lamp plant with PID controller that has a stable temperature at the *setpoint* is able to incubate eggs with a time span of 19 days. While the results of a 25 Watt plant that has temperature stability up and down from the *setpoint* is able to incubate eggs with a time span of 21 days. The following are Table 2 and Table 3 of hatchery testing results of each plant.

Table 3. Test Results of 15 Watt Plant Hatching

Plant 15 Watt Parallel (10 eggs)			
Egg Hatching			Eggs Not Hatching
70%			3 Eggs (30%)
Normal	Defect	Dead	
7	0	0	

Table 4. Test Results of 25 Watt Plant Hatching

Plant 25 Watt Parallel (10 eggs)			
Egg Hatching			Eggs Not Hatching
80%			2 Eggs (20%)
Normal	Defect	Dead	
7	0	1	

6. CLOSING

6.1. Conclusion

Based on the research, it is concluded that the monitoring and temperature control system in egg incubator for PID controller has been successfully integrated automatically with PWM method in incandescent lamp. To apply the PID control on the egg incubator plant using the egg incubator method is by identification method of ARX system with the constant value of Kp = 3.9956, Ki = 0.361, Kd = 0 for the parallel 15 Watt plant and the constant value of Kp = 5.714, Ki = 0.351, Kd = 0 for the plant 25 Watt parallel. Using these constants, the response of the control system is able to stabilize the egg incubator's temperature. In PID control plant test, the 15 Watt plant produces slower response for the rise time of τr = 2178 seconds, delay time τd = 1089 seconds. While the 25 Watt plant response rise time of τr = 1244 seconds, delay time τd = 622 seconds. But for a steady-state response (stable) the 15 Watt plant is capable to produce faster response of τs = 2178 seconds than the steady-state plant 25 Watt of τs = 5010 seconds. The steady state error value of 2.7% indicates that the temperature control runs well in ambient conditions with 70-80% hatching rate of eggs.

6.2. Suggestion

Based on the conclusion above, there are some suggestions that can be done for the development of the system to get maximum results that is to use a more accurate and precise sensor such as SHT 11 type, to apply the air humidity control system on the plant, to apply rotary shelf system automatically, to apply the UPS as a backup power Electricity if the electricity goes off, to implement an online monitoring system or Internet Of Thing (IoT), and to change the controller of adaptive, fuzzy logic and neural network (ANN) controls to reduce the steady state error value .

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