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Optimization of Pid Controler In Temperature Control System Processes Pasteurization of Milk

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ABSTRACT : *Pasteurization is one of the heating process done on fresh milk so it becomes a product that has a longer shelf life. By controlling the temperature in the pasteurization process is expected to be able to kill pathogenic bacteria that endanger human health, so it is important to do the temperature control. In manual and conventional controls cause temperature instability and possible many errors occur. So as to affect the quality of the production of pasteurization process of milk is not good. Therefore, in this study developed a controller to maintain temperature stability in milk pasteurization process. The control system used for this control is the PID control implanted on Atmega 16 to control electrically heating element actuators that get input from PT 100 temperature sensors. The test results for heating of milk starting from 30 ° C to 65 ° C. Using Tuning Ziegler Nichols method, Kp = 18, Ki = 0.45 and Kd = 180. The system was tested at temperature setting 65˚C and milk volume of 10 liter, with graph showing time rise (Tr) = 2400s, time delay Td) = 140 s, peak time (Tp) = 2700s, down time (Ts) = 3700 s, maximum overshoot (Mp) = 2 ° C and steady state error 1.5%.*

Keywords *- Pasteurization, milk, PID-controller, censor , temperature*.

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I. INTRODUCTION

Background Of Problems

Milk is an ingredient beverages that have high nutritional content but are vulnerable to bacteria so they are not durable and easily broken (stale) ***[1]*** Therefore, the need for milk processing to optimize the quality and durability of milk which could eventually reduce keruguian farmers in distributing milk and reduce manpower in processing the milk. One example is the pasteurization of milk processing.

Pasteurization is a heating process performed on fresh milk so that it becomes a product that has a longer expiration. The pasteurization process may be performed under high temperatures or low temperatures which can be applied ***[1].*** In the heating process by controlling the temperature is expected to be able to kill pathogenic bacteria that endanger human health and minimizing the development of other bacteria, either for heating or during storage ***[3].***

Therefore, to overcome these problems required a tool pasteurized milk with the control system to obtain the desired stable temperature automatically. So it will be an effective and stable temperature corresponding requirements of pasteurized milk.

In this study tested using methods LTLT *(Low Temperature Long Time),* which is heating the milk to a temperature of 63-65 ° C and maintained at that temperature for 30 minutes ***[3].*** In order for the milk pasteurization process can be done automatically, the heating process is done using a controller with PID control. P (proportional), I (integral) and D (derivative) with the overall objective to accelerate the response of a system, eliminating the offset and produce large initial changes (oscillations). With the use of PID temperature controller can control the time efficiently and effectively and maintain stable temperature of the pasteurization process ***[9].***

Research Objectives

The purpose of research is to find the value optimization of PID control system using the method of milk pasteruisasi LTLT (Low Temperature Long Time), which is heating the milk to a temperature of 63-65° C and maintained stable for 30 minutes. ***[9].***

II. SOFT SET THEORY

2.1 Pasteurisasi Susu

Scope Milk Processing Industry

Dairy processing industry includes manufacturing business: powdered milk, sweetened condensed milk, sour milk, cream / cream milk including preservative such as sterilization and pasteurization. Dairy processing industry in general using fresh milk as a raw material. In addition to fresh raw milk, the industry also needs additional materials such as sugar, cream, vegetable oil, and others that can be processed into other processed products.

Diversified kinds of dairy products include: liquid milk (UHT, pasteurization), milk powder, condensed milk, cheese, butter, yogurt, and ice cream. ***[2].*** Fresh milk and other dairy products are presented in the form of industrial tree in Figure: 1.

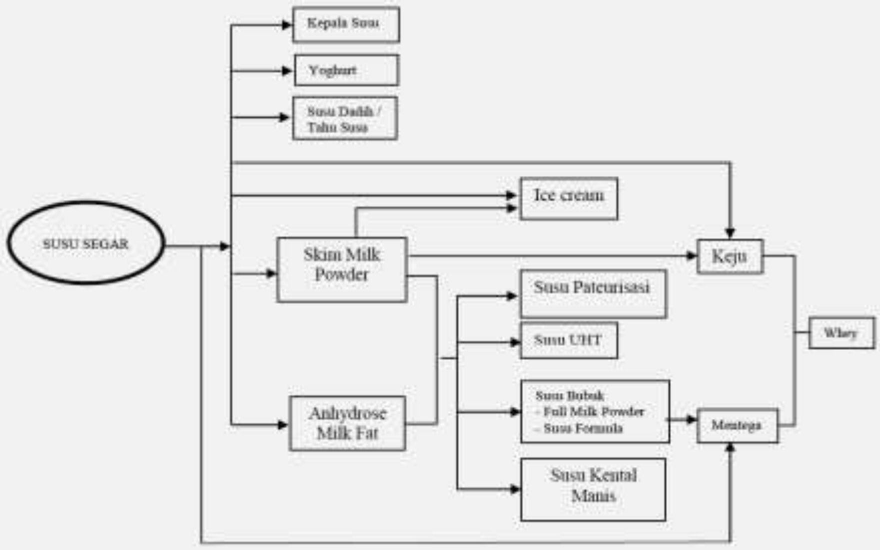


Figure 1. Indonesia Industrial Tree Forms *[2].*

Research institutions

To conduct dairy research, both from fresh raw milk, production processes, product diversification, and development of machinery / equipment. Figure 2, shows the relationship of milk processing industry.

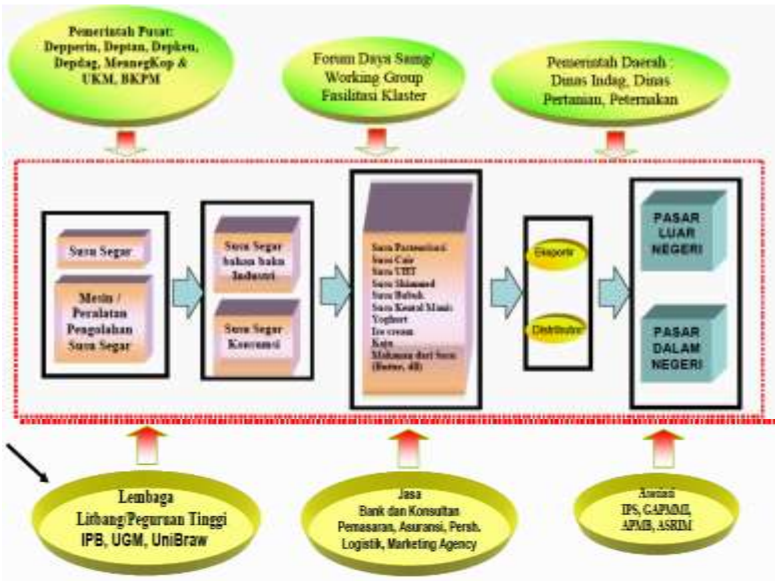


Figure 2. Indonesian Milk Processing Industry Linkage Framework *[2]*

Pasteurized Milk

Pasteurization of milk is heating milk at temperatures below the boiling point with the intention only kill germs or pathogens, while the spores are still alive ***[4].*** Additionally, the pasteurization process is beneficial to extend the shelf life of materials or products, may give rise to taste better on the product, and can kill the enzyme phosphatase and catalase, the enzyme that makes the milk quickly broken ***[2].*** There are two methods used in milk pasteurization process, namely :

1. LTLT *(Low Temperature Long Time).* LTLT method is basically carried out by heating the milk to a temperature of 63-65 ° C and maintained at that temperature for 30 minutes.
2. HTST *(High Temperature Short Time).* Medium HTST method is the process of heating to a high temperature in a short time, is done by heating the milk for 15-16 seconds at a temperature of 73-75 ° C or more ***[6].***

PID *(Proposional Integral Derivativ).*

A PID controller to determine the precision of an instrumentation system with the characteristics of their feedback on the proficiency level system. PID control component consists of three types: Proportional, Integrative and Derivative. All three can be used together or individually depending on the desired response to a device. Proportional Control action has advantages when riding fast and stable, integral control action of its ability to minimize errors, and differential control action has advantages dampen the response shortage or excess response ***[8].***

Table 1. Responses to the PID Control System

A. Parameter Changes ***[1].***

Closed Loop Response	Rise Time	Overshot	Fall Time	Steady-state error
Proposional (Kp)	Decreased	Increased	Small changes	Decreased
Integral (Ki)	Decreased	Increased	Increased	Lost
Derivative (Kd)	Small changes	Decreased	Decreased	Small changes

In continuous time, PID controller output signal is defined as :

$$u(t) = K_p \left(e(t) + \frac{1}{T_i} \int_0^t e(t)\, dt + T_d \frac{de(t)}{dt} \right)$$ ……………………….. (1)

With :

u(t) = *PID controller output signal*
Kp = *proportional constant*
Ti = *integral time*
Td = *Rice Time*
Ki = *integral constants*
Kd = *constant Fall*
e(t) = *error signal*

Thus, the transfer function of a PID controller (in the s domain) can be expressed equation in Figure 3. ***[4].***

$$G_c(s) = K_p + \frac{K_i}{s} + K_d s$$ ……………………………………… (2)

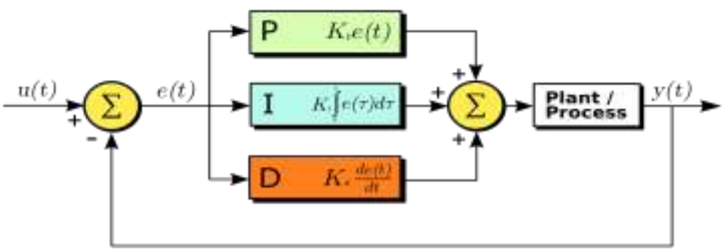


Figure 3. Block Diagram System PID *[8].*

Temperature Sensor (PT 100)

PT100 Sensor (Figure: 4) is a type of RTD sensor. Sensor RTD (Resistance Temperature Detector) detects the temperature based on the resistance value or the value changes in metal constituent. PT100 RTD is used in stainless. PT100 RTD cable consists of 3 pieces consisting of two types: A and B. Cable Cable B has two branches that have the same function, because the ends diparalel. Average resistance changes - Average sebersar 0.39Ω / ° C ***[5].***

Figure 4. Temperature Sensor PT100 *[5]*

III. RESEARCH METHODS

Population and Sample Research

Make a Mechanical Design

Tube where milk container made using stainless steel construction materials such as described in Figure 5. The maximum capacity of the material is limited to 20 liters of milk.

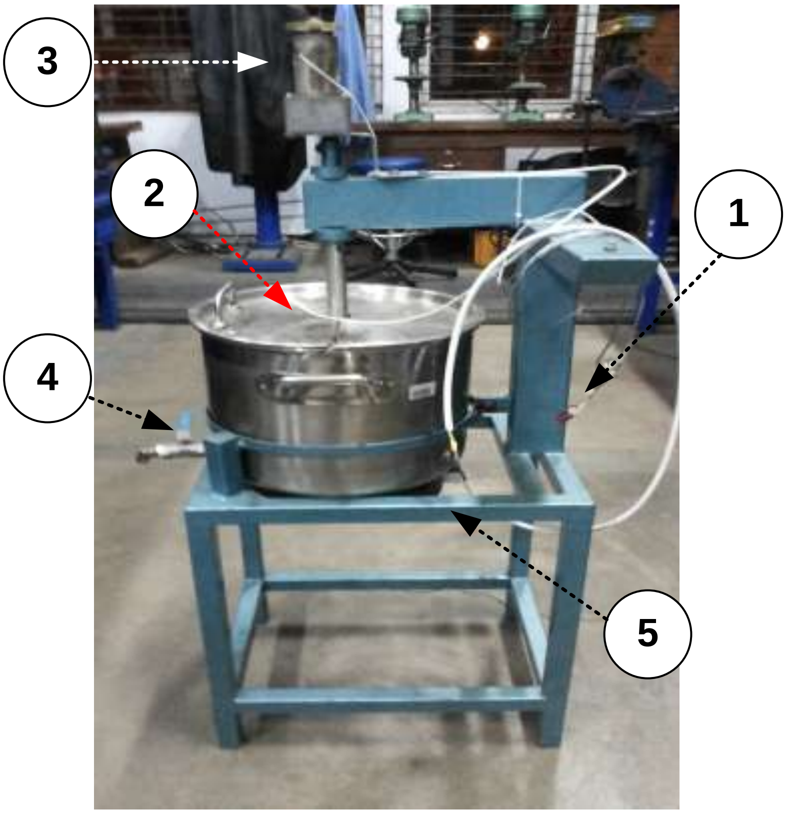


Figure 5. Tubes Mechanical Design Milk Pasteurization

Designing Systems

Creating such a system block diagram shown in Figure 6. The control of heater systems use closed loop control system, there diamana feedback to reduce errors and produce the desired outcome. Figure 7, shows the diagram of the system controller.

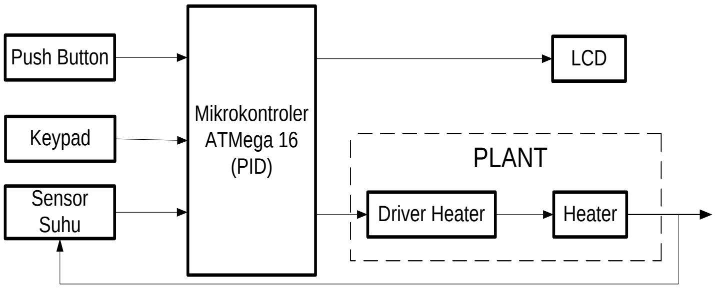


Figure 6. Block Diagram System

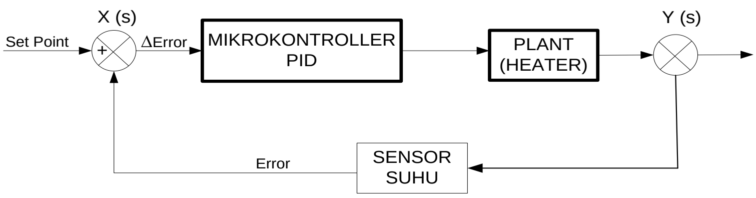


Figure 7. Block Diagram of Plant Controller

Modeling System

PID *(Proportional Integral Derifativ)*

The design of PID control in the process using a formula that requires feedback readings of temperature sensors PT 100. The formula used to calculate the oscillation in a program. PID Controller block diagram shown in Figure: 7. The first step to do is take the response of the plan obtained experimentally with the input unit step, to get the value ***tu*** and ***ta***, as shown in Figure: 8. and Table 2. show value of Modeling Strejc.

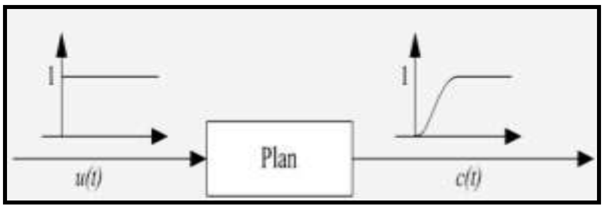


Figure 8. Plant Response Against Input Unit Step

Table: 2, Modeling Strejc *[8]*

N	T_a/T	T_u/T	T_u/T_a
1	1	0	0
2	2.718	0.282	0.104
3	3.695	0.805	0.218
4	4.463	1.425	0.319
5	5.119	2.100	0.410

Using a Taylor series, the roots of the characteristics can be calculated as follows :

a). To order n = 1, the maximum degree of the numerator is zero order :

$$G(s) = K \frac{e^{-\tau s}}{(Ts+1)^{1}} \qquad \text{...} \quad (3)$$

b). To order n = 2, the degree of the numerator is the maximum order I:

$$G(s) = K \frac{\tau e^{-\tau s} S + e^{-\tau s}}{(Ts+1)^{2}} \qquad \text{...} \quad (4)$$

c). To order n = 3, the degree of the numerator is profuse Order II:

$$G(s) = K \frac{\frac{\tau}{2} e^{-\tau s} S^{2} + \tau e^{-\tau s} S + e^{-\tau s}}{(Ts+1)^{3}} \qquad \text{..}(5)$$

Having obtained the transfer function using sterjc modeling, calculation results obtained transfer function using taylor series. Furthermore simulated using matlab application program. (Figure 9). Simulation results obtained model of the system that has been designed, it can be determined the value of *L* and *T* of the response curve.

Table 3. PID Parameters With the Reaction Curve Ziegler-Nichols Method *[8].*

TipeKontroler	K_p	T_i	T_d
P	T/L	~	0
PI	0,9 T/L	L/0.3	0
PID	1,2 T/L	2*L*	0,5*L*

Having obtained the transfer function of the unit step next step is to calculate the value of *Kp, Ti,* and *Td* in accordance with the rules of *Ziegler-Nichols.*

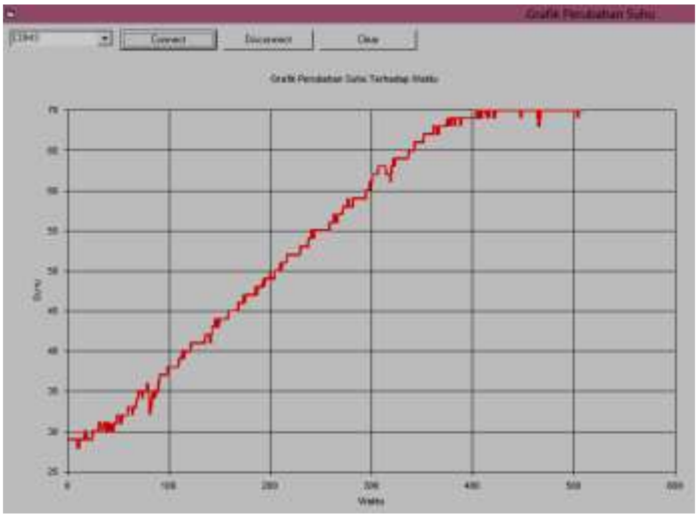


Figure 9. Results of Initial Response Unit Heater Step Toward

From the graph of Figure: 14, obtained ***Tu*** and ***Ta*** = 220 and 3000. So to determine the order used in modeling strejc can be done by :

Tu/Ta = 0.085

With the acquisition value of 0.085, the asset is considered near 0.1036 which is of the order of 2. Then the value of T and can be obtained by modeling strejc table.

- ***Ta/T*** = 2.71
  T = Ta/2.71
  = 300/2.71
  = 110.7 sec
- ***Tu*** = Ta x (Tu/Ta)
  = 300 x 0.085
  = 25.5 sec
- τ = Tu - Tu'
  = 22 – 25.5
  = 4.8 sec

Where :

$S = \frac{1}{T} = \frac{1}{110.7} = 0.010$

Using a Taylor series, the roots of the characteristics can be calculated as follows :
To order n = 2, the degree of the numerator is the maximum order of II

$$G(s) = K \frac{\sigma e^{-\sigma s} S + e^{-\sigma s}}{(Ts+1)^2}$$

$$= K \frac{4.8e^{-4.8X0.009} S + e^{-4.8X0.009}}{(110.7s+1)^2}$$

$$\text{Diperoleh : } K = \frac{Yss}{Xss} = \frac{61.5}{65} = \mathbf{0.94}$$

Simulation System

The results of calculation of transfer function then simulated using Matlab application program, shown in Figure: 11, the result of the transfer function is shown in Fig: 10

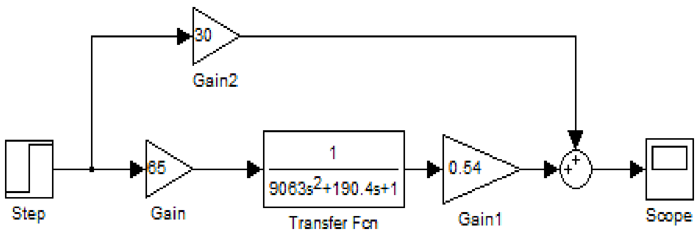


Figure 10. Block Diagram PID Transfer Function Method with Strejc.

PID parameters are obtained directly from the simulation graph :
L = *20 s*
T = *300 s*
Then the value of Kp, Ki, and Kd can be calculated as follows :

Kp $= 1{,}2\ x \frac{T}{L} = 1{,}2\ x \frac{300}{20} = \mathbf{18}$

Ti = *2 x L = 2 x 20 = 40*

Td = 0,5 x L = 0,5 x 20 = 10

While the value of Ki and Kd can be searched by the following equation:

*Ki = **0.45***

*Kd = Kp x Td = 18 x 10 = **180***

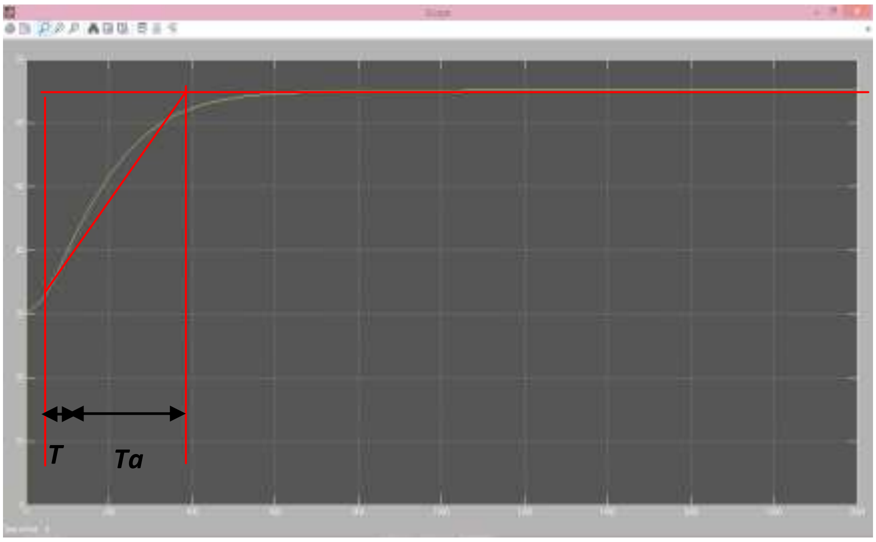


Figure 11. Simulation Results Matlab

Designing Circuits

Design Temperature Sensor

The series of temperature sensors PT 100. The device is used which has properties that are sensitive to changes in temperature by 1 ° C range change will result 0:39 Ω resistance range and has a range of -200 ° C to + 800 ° C. Known as the sensor is calibrated PT100 at 0 ° to the resistance value of 100 ohms. **Figure 12**, showing the temperature sensor circuit. PT 100 temperature sensor circuit designed is the application of a combination of the Wheatstone bridge circuit with op-amp (amplifier).

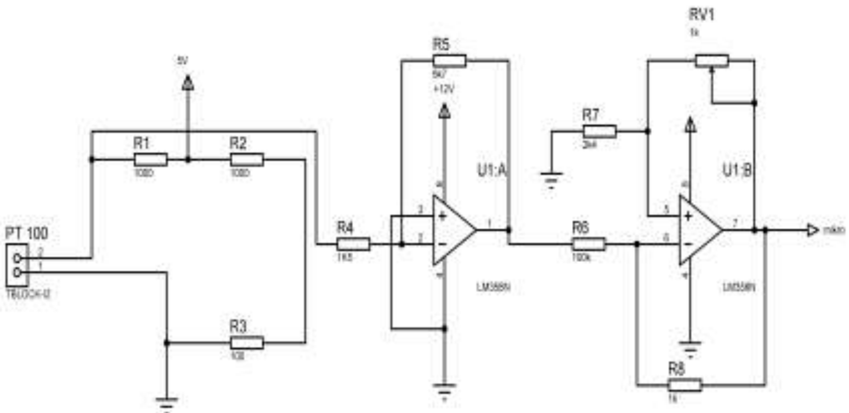


Figure 12. Circuits Design of Sensor PT-100

With the aim to meet the analog input voltage range Atmega 16 between 0 and +5 Vdc. Inverting amplifier consists of two op-amps in construction as an inverting amplifier, whereas R4, R5, R6 and R8 as reinforcement.

So to calculate the value of Rin and Rf if known value Av = 45 and Vout = 5V. So that the value of Vin = Vout the comparison value R value of 45. Then the comparison should be the strengthening of the first op amp amplifier which is 4.5x resistance. And strengthening of the second op amp is 10x resistance.

Design of Embedded System Atmega 16

This study used ATmega 16 microcontroller as the main controller 16 in the Electoral Atmega adjust the capacity of the program to be created, the storage capacity on the microcontroller Atmega 16 is large enough that 16 Kbyte as indicated on the datasheet. So that in this research, microcontroller Atmega 16 the most appropriate. Pictures of the circuit for minimum use Atmega system shown in Figure: 13.

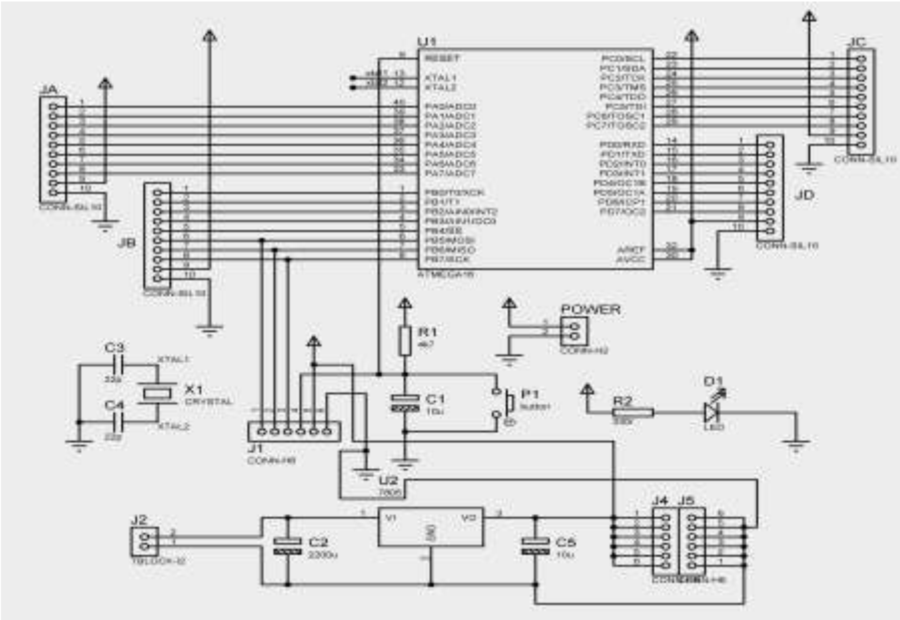


Figure 13. Minimum System Circuit Atmega 16

3.3.3 Design of Circuit Driver Heater

According to the datasheet, then the condition that the MOC ON, VF> 1.2V at IF = 100μA. **(Figure 14**) In addition the microcontroller V_{oh} = 5V and Ii / O = 40mA. It can be calculated a minimum value and a maximum of *R1*.

$$R\ min = \frac{VOH}{I\ I/O} = \frac{5V}{40mA} = 125\Omega, \text{ and}$$

$$R\ max = \frac{VF}{IF} = \frac{1.2V}{100\mu A} = 12K\Omega.$$

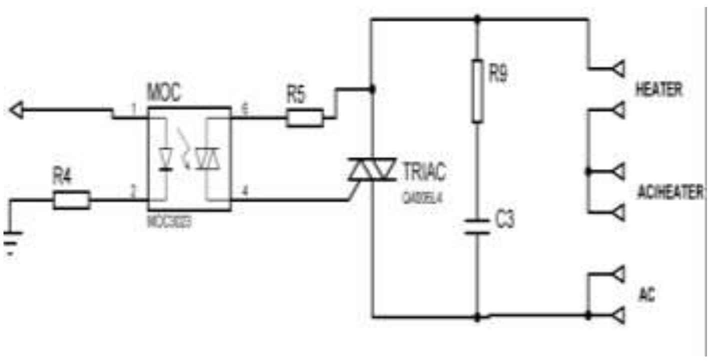


Figure 14. The Circuit Design Driver Heater

IV. RESULTS AND DISCUSSION

Testing Controls Proportional, Integral, Derivative (PID)
Data Testing Results (Figure 15).

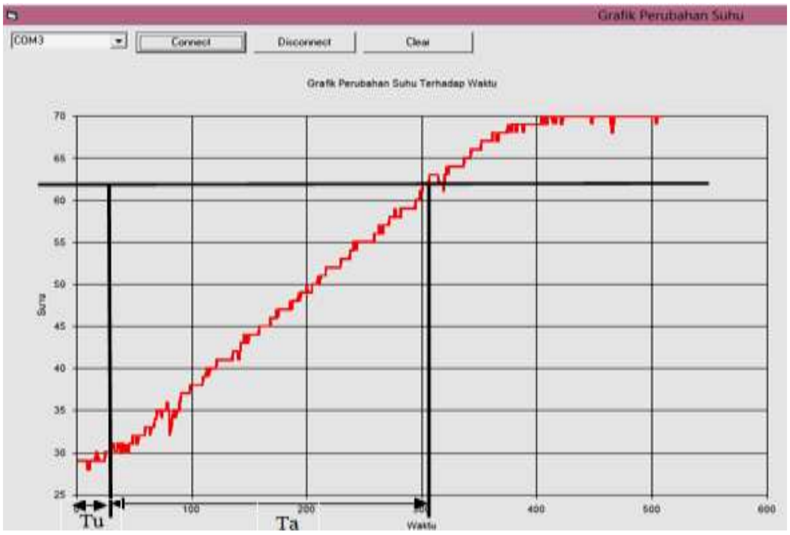


Figure 15. Temperature Graph Initial Response Against Time

Discussion-1.

After obtaining the response graph by providing value *Kp = 18, Ki = 0:45* and *Kd = 180,* graph in Figur 16 shows the rise time *(Tr) = 2400s,* the delay time *(Td) = 140 s,* the peak time *(Tp) = 2700s,* down time *(Ts) = 3700 s,* the maximum overshoot *(Mp) = 2° C* and a steady state error: *1.5%.*

With its use of PID control (Figure: 21) the process of heating milk, the temperature rises very slowly, but time is achieved at the time by the PID control more quickly and can mecapai steady state fairly quickly than without the PID control

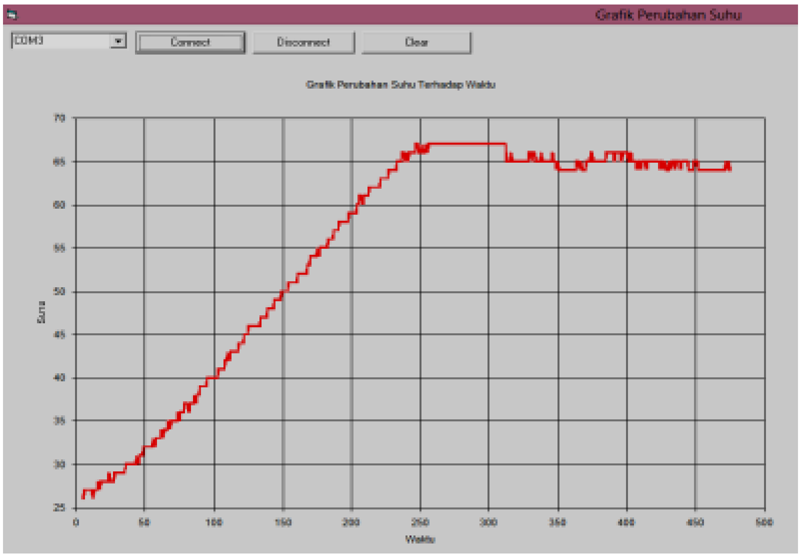


Figure 16. Using Response Graph PID Controller.

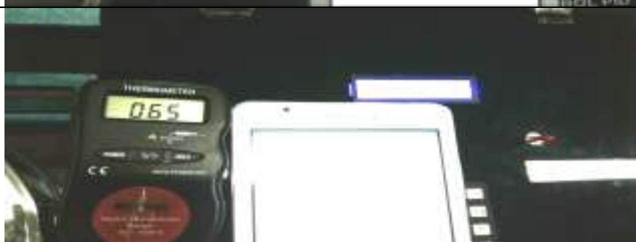
Testing and Measurement Systems

After testing the simulation, the next step to test the real system. Using PID control as the pasteurization process of milk with a maximum temperature setpoint: 65 ° C using milk capacity of 10 Liter and 20 Liter and also show time / long heating up to the setpoint. 65 ° C. Each performed a total of three times of testing. Data from each test are given in Table 4 and Table.5.

Table 4. Results of Stabilized Temperature Testing with Materials Test System of 10 Liters Milk

No.	Visual Data of Temperature Testing Results
1.	
2.	
3.	

Table 5. Results of Stabilized Temperature Testing with Materials Test System of 20 Liters Milk

No	Visual Data of Temperature Testing Results
1.	
2.	
3.	

Discussion-2

Visual data in Table 4 can be seen, with the use of 10 liters of milk test system in test 3 times. In the first test time can be achieved until the setpoint is: 16 minutes and 23 seconds error for temperature readings: 0%. In the second test time can be achieved up until setpoint is: 15 minutes 55 seconds with the temperature reading error: 1.5%. While in the third test of time got up until setpoint is reached: 14 minutes 25 seconds with the temperature reading error: 1.5%.

In testing the system by using a capacity of 10 liters of milk, there is a time difference that reached up to the setpoint, but these differences can still be said to be good because there is only a difference of a few seconds. While the temperature readings of the thermometer (reference) to the LCD display has the average - average error of: 1%, it is still tolerable for temperature readings between Thermometer with LCD display no more than: 5%.

Discussion-3

Visual data can be seen in Table 5, using 20 liters of milk test materials testing 3 times. In the first test time can be achieved up to setpoint that is: 31 minutes 25 seconds with the temperature reading error of 0%. In the second test time can be achieved up to setpoint that is: 31 minutes and 26 seconds with a temperature reading of 0% error. While in the third test of time available until the setpoint is reached: 30 minutes and 20 seconds with a temperature reading of 0% error.

Visual data in Table 4.5, the system test using milk capacity: 20 liters, there is a time difference that reached up to the setpoint, but these differences can still be said to be good because there is only a difference of a few seconds. While the temperature readings can be said to be very good because it has the average - average error of 0%.

V. CONCLUSION

5.1 Conclusion

The results of the analysis and discussion in this study a number of conclusions and suggestions are:

1). Performance PT100 temperature sensor device is quite linear so it can be used as a temperature sensing device in the research process pasteurized milk which only has an error of : 0.03%.

2). In the process of heating milk using PID control with the test materials milk 10 liters it takes time for 2400 seconds with a value of Kp = 18, Ki = 0:45 and Kd = 180 with the response graph showing the rise time (Tr) = 2400s, the delay time (Td) = 140 s, the peak time (Tp) = 2700s, the down time (Ts) = 3700 s, the maximum overshoot (Mp) = 2 ° C and a steady state error 1.5%

3). In the test system with test materials as much milk: 10 liters and 20 liters of the time required to achieve setpoint between test experiments 1 to 3 faster (test experimental-1 slower), because the required preconditioning on mechanical systems with further testing (2 and 3) different. On testing and to 2 to 3 hotter temperatures in the tank so that the time taken faster.

4). While temperature readings in testing the system with a capacity of 10 liters of milk and 20 liters is very good because it has a mistake (error) at: 1% and 0%, due to PT100 temperature sensor has a linearity and high sensitivity.

5.2 Implications

1). To develop the tool should use different control systems, eg using fuzzy logic control. Of interest to compare the response generated by using the other controls.

2). To design constants Kp, Ki and Kd are advised to use software other than Visual Basic. Of interest to compare the response generated by using other software.

3). Adding a cooling system (cooling system) after the milk pasteurization process is completed so that the results can be a maximum of pasteurized milk.

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