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DESIGN OF TEMPERATURE PID CONTROL SYSTEM IN MN-PHOSPHATING PLANT

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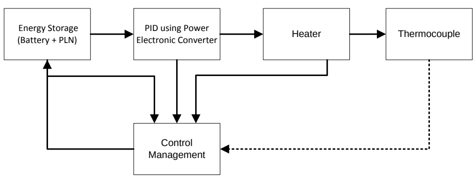
Didi Istardi, Elgam Salehul F, and Rifqi A*

Electrical Engineering, Batam Polytechnics
Batam, Indonesia

*Corresponding author
istardi@polibatam.ac.id

Graphical abstract



Abstract

In oil and gas indutry, drill pipe required standar specifications that must be met. One of the requirement are the connection process or coupling where the coupling connector must be coated with phosphate process. Mn phosphate as one of the phosphating system that use metal coating. There are some reasearch in control on heating process such as in furnace, heat exchanger. This paper was implement the PID control in heater that was used in MN-phosphating plant. The PID control in MN Phosphating plant was simulated in MATLAB/Simulink software with the tuning of PID gain. The feedback of the system using the thermocouple as a sensor. Output of simulation was implemented in MN phospating plan in PT Indonesia. The result show that the implemented PID control improve the performance of the MN-phosphating plant at 30% and increase the lifetime of heater until 8 weeks.

Keywords: PID Control, Matlab, heater, metal coating, MN-phosphating

1.0 INTRODUCTION

Metals Phosphating is one of the most important of surface treatment methods and a number of modern metal finishing procedures would not be possible without it. Phosphating process can be defined as the treatment of a metal surface so as to give a reasonably hard, electrically non-conducting surface coating of insoluble phosphate which is contiguous and highly adherent to the underlying metal and is considerably more absorptive than the metal [1]. There are some phosphating systems which have been implement in industry, such as: zinc phosphate, iron phosphate, manganese phosphate. Such phosphating systems are predominantly applied to iron and steel, as well as zinc surfaces whereas other metals which can be phosphated, e.g., aluminum, magnesium, are less commonly processed by this method.

Manganese phosphate coating has the highest hardness and superior corrosion and wear resistances of general phosphate coatings. Manganese phosphating is extensively employed to improve the sliding properties of engine, gear, and power transmission systems and also in oil and gas equipment. Manganese phosphated coatings will improve corrosion resistance that can be found in virtually all branches of the metal working-industry. Metal treatment process using Manganese phosphate - 201 (Mn-201) providing crystal layer that envelops the metal surface that serves to increases the resistance in corrosive environments (anti-rust). Mn layer will be attached to the surface easy compare to other material that can reduce the risk of scratches during the process of phosphating.

The steps in manganese phosphating process are; cleaning, water rinse (rinsing), treatment process with manganese phosphate, flushing, and drying. This process need electric heater to maintenance temperature. According to the standard and manual of the plant, the temperature should be between 90^0C - 98^0C. The heater will be damage if the heater was run constantly for a day due to due to melting of material which makes the sort of circuit and interruption of the heating element in the heater. Selection of the heater and the volume of water will also greatly affect the lifetime of the heater itself. This problem can be solved by maintain the temperature.

The heater control despite the different plant, among others, the use of PID control system engine furnace carried out by [2] that evaluated the performance of flow PID controller design for the temperature control in furnace. Research on heat exchanger control system has also been carried out by [3]. The main purpose of the system is the heat exchanger system heat exchanger is to transfer heat from hot fluid to cold fluid. The temperature control system that uses fuzzy logic also be done by [4].

This paper will design and analysis the PID Control of heater in MN-Phosphate plant. The paper is organized as follows: In the next section, a system design of the plant is presented. Section III and IV a presents results of simulation using MATLAB®/Simulink® software, implementation, and discussion of the results. Finally, the conclusions are made in section V.

2.0 SYSTEM DESIGN

2.1 Study Design

The MN-Phosphating plant system can be seen in the block diagram of Figure 1. Where the block diagram indicates that the PID control controls the heater and the heat from the heater to be fed back to the PID by thermocouple.

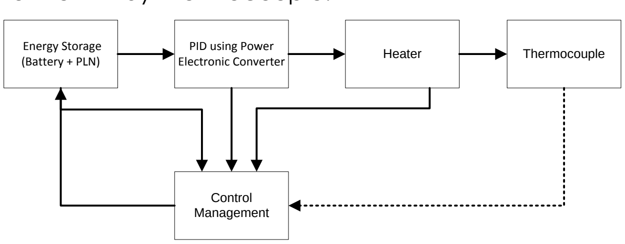


Figure 1 Block diagram of MN-Phosphating plant system with PID Control

Within the system, energy is stored in the battery and come from power plant. A power electronics converter connects the energy storage to a heater. The voltage and current output of the storage energy are maintained to match the condition of MN-Phosphate with 90^0C - 98^0C. A thermocouple as a temperature sensor that give information to control management. Thermocouple as heat sensors provides input to control management. Control management used as a PID control which gives orders to the contactor and power electronics converter that while turn on and turn off the heater. The control management will maintain the heater at desired temperature that give signal to the PID controller.

The heater that used in this paper must match with some parameters such as volume of water, set the desired time, set the required temperature. With a volume of 1800 liters of water to the set temperature of 95° C is required 178KW/h is taken from the table provided heater manufacturer [6]. Due to limitation of heater operation (3 hours) and volume of tank, there are 17 heater that used in the MN-Phosphating plant system.

The process in heater MN phosphating plant can be shown in Figure 2.

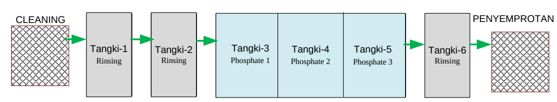


Figure 2 MN phosphating process

The Figure 2 shows the process of the plant begin with cleaning process. Cleaning process is a process of cleaning material using liquid soap. Then in the second stage, the material is inserted in the tank 1 and tank 2 before for rinsing process using plain water to remove residual soap on the material. After a certain material cleared and then inserted in the tank 3, 4, or 5 which is a process that is phosphate coating process the material. After completion of the process of phosphate material is inserted in the tank for flushing residual chemical rinsing attached to the material. Finally the process of spraying by using the wind to dry the material.

2.2 Mathematics Modelling System

The common model of the heater for temperature control based on thermodynamics laws the process of
diversification of temperature is actually the process of acquisition and loss of energy. The dynamics equation in Laplace transform can be express as [7]:

$$G_s(s) = \frac{1}{Ts+1} \tag{1}$$

Where T is time constant.

The heater is part of MN-Phosphasting process, therefore the complete mathematic model of the process system are

$$G_s(s) = \frac{1}{1080s^2 + 3225s + 0.95} \quad (2)$$

This transfer function of the system was retrieved from the some experiment of the operation of the system with different load and system on tank hot water. This model was use second order plus time delay that have general form:

$$G\ \ (s) = \frac{K_p e^{-\tau_D s}}{(\tau_1 s + 1)(\tau_2 s + 1)} \quad (3)$$

Here Kp is the process gain, τ_D is the time delay, τ is the time constant of first order plus time delay system, τ_1 and τ_2 are the time constant of second order plus time delay system. The parameters are obtained from open loop step response data or frequency response data. The time delays are measured from the step response data.

The PID control in Laplace transform can be model as equation:

$$G_c(s) = Kp + Kd.s + \frac{Ki}{s} \quad (4)$$

Where Kp is Proportional, Kd derivative, and Ki integral gains.

There are different tuning methods of PID controller. Some methods are empirical methods (process reaction curve), some methods are based on frequency response analysis of the system and other methods are based on minimization of performance measures. Despite advances in PID tuning methods the ground reality is that in most of the cases, PID controller is tuned using trial and error method.

In this paper, the Matlab software use to find gain in this controller as shown in Figure 3.

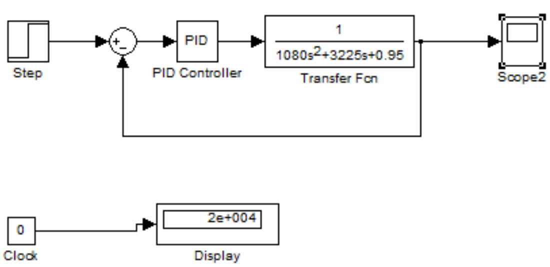


Figure 3 Tuning model with PID Control

2.3 Matlab/Simulink Model System

This MN-phosphating is implemented in MATLAB/Simulink as shown in the Figure 4.

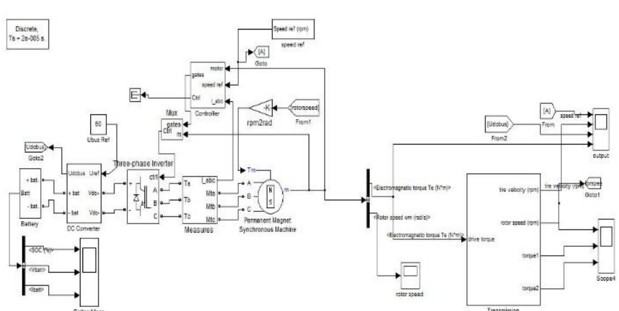


Figure.4 MATLAB/Simulink model of PID controller design for the heater temperature control

Figure 4 shows that the system's reference input is the temperature profile that represents the load profile of the system. There are six main blocks, each representing a component of the MN-phosphating Plant system.

3.0 RESULTS AND DISCUSSION

3.1 Full Hardware Setup

Wiring diagram for electrical installation of the system can be seen in Figure 4. The schematic diagram of the control panel can been seen in Figure 5 and the wiring diagram of heater can been seen in Figure 6.

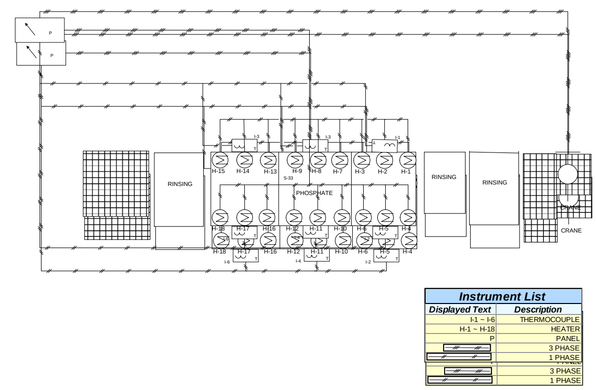


Figure 4 Single line diagram MN-Posphating Plant

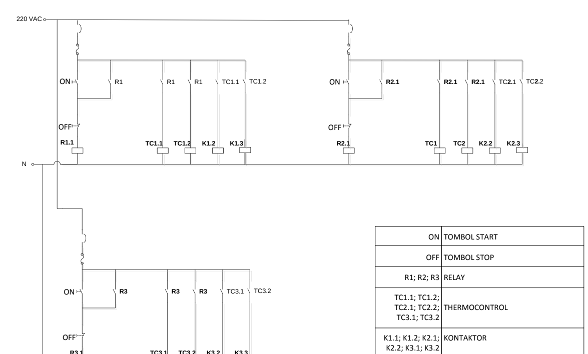


Figure 5 Schematic diagram of control panel

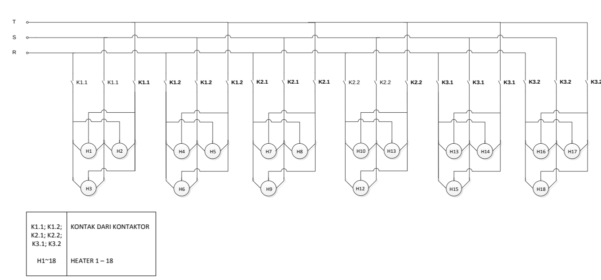


Figure 6 Wiring diagram of the heater

In Figure 6 show the heater instalation that use three phase power supply. There are 18 heaters that supply hot temperature to the tank.

3.2 MATLAB/Simulink Simulation

Firstly, the Mnphosphating plant was evaluated and simulated using Figure 4. The result shown in Figure 7 that the PID controller was not implemented in the system.

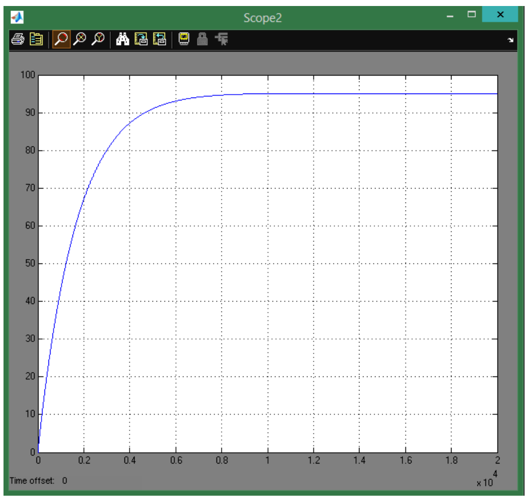


Figure 7 Result of MN Phosphating plant without controller

In Figure 7 shows temperature on the water reach steady state at 95°C within 3 hours and the heater still continues to work. The system was change with adding the PID controller as show in Figure 4. The value of PID gain was simulated by Figure 3 that got the value of proportional gain = 2, the value of integrator gain = 5.95 x 10^{-4}, and the value of derivative gain = 20. The result shown in Figure 8.

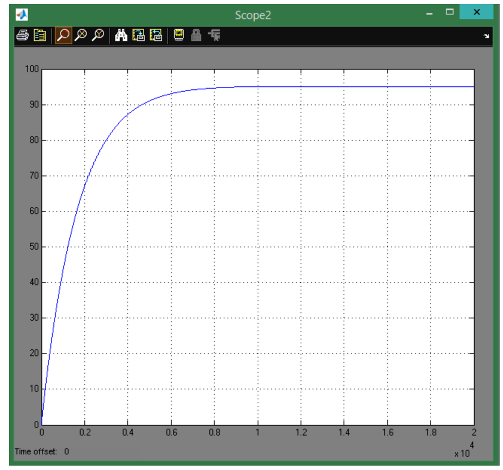


Figure 8 Result of MN Phosphating plant with controller on no load capacity

Figure 8 shows that the steady state temperatures at 95 °C with unity feedback. The calculation of PID gain from the results of experiments in which e(t) is considered one due to the difference between thermocontrol measurement with thermocouple input. The value of m (t) is output value of P, I, and D are different and taken from the value of P, I, and D are cool. The value of PID gain are K_p 2, K_d 20, and K_i 0.000595. This gain was change due to changing of capacity.

3.2 Result of the System Implementation

The PID MN-phosphating plant controller was implemented in three tanks. The result of temperature monitoring will be calibrate with measurement equipment. The result was shown in Figure 9.

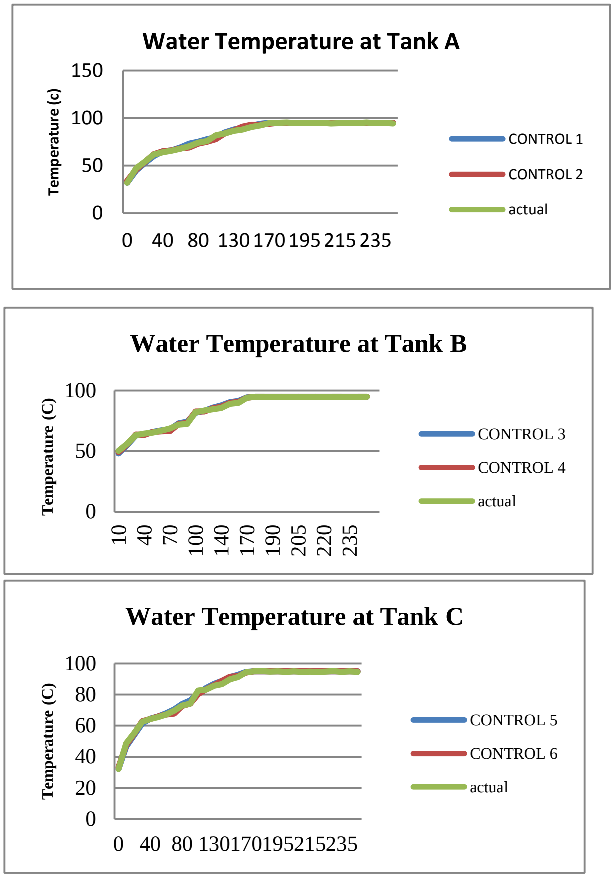


Figure 9 Calibration of Heater and Temperature monitoring at Tank A, Tank B, and Tank C

From Figure 9 show that the heater and temperature control have a exact measurement. The error of the monitring are 1%. With this error, the heater and monitoring system was implemented with load capacity.

Thermocouple that uses in the system have a limitation gain. The minimum gain of thermocouple are 1. Therefore, the PID control gain in sub-chapter 3.2 was change. The new PIC control gain are proportional gain = 2000, the value of integrator gain = 6, and the value of derivative gain = 20. The new PID control gain also affect the setting of thermocontrol to 3 minutes on and 6 minutes off in normal capacity. If the load capacity was increased, the water temperature in tank was reduced 3⁰C that the water temperature was be 92⁰C.

The PID control maintan the temperature in range temperature in around 20 minutes. The time depend on the load capacity and reduced temperature. The PID control also set the off heater in 5, 6, and 7 minutes sequency.

This new system was check again in six weeks after instalation. The result of the performance of the system can been seen in Table 1,2 , and 3.

Table 1 Load Capacity (A) Performance at tank A

WEEK / HEATER	Octiber		November				December	
	1	2	3	4	5	6	7	8
H1	5.1	5.0	4.9	4.8	4.6	4.4	4.3	4.2
H2	5.2	5.1	5.0	4.9	4.7	4.5	4.4	4.3
H3	5.2	5.1	4.9	4.8	4.6	4.4	4.3	4.1
H4	5.0	4.8	4.7	4.5	4.3	4.0	OFF	
H5	5.0	4.9	4.7	4.6	4.4	4.1	OFF	
H6	5.2	5.0	4.9	4.7	4.5	4.2	4.0	OFF

Table 2 Load Capacity (A) Performance at tank B

WEEK / HEATER	Octiber		November				December	
	1	2	3	4	5	6	7	8
H7	5.3	5.2	5.1	5.0	4.8	4.7	4.6	4.5
H8	5.1	5.0	4.9	4.8	4.6	4.5	4.4	4.3
H9	5.0	4.8	4.7	4.5	4.3	4.0	OFF	
H10	5.2	5.0	4.9	4.7	4.5	4.2	4.0	OFF
H11	5.2	5.0	4.8	4.7	4.5	4.1	OFF	
H12	4.9	4.8	4.6	4.5	4.0	OFF		

Table 3 Load Capacity (A) Performance at tank C

WEEK / HEATER	Octiber		November				December	
	1	2	3	4	5	6	7	8
H13	5.1	5.0	4.9	4.8	4.6	4.4	4.3	4.2
H14	5.0	4.9	4.8	4.8	4.7	4.5	4.4	4.3
H15	5.3	5.2	5.0	4.9	4.8	4.5	4.4	4.2
H16	5.2	5.0	4.8	4.6	4.4	4.0	OFF	
H17	4.9	4.7	4.6	4.4	4.1	OFF		
H18	5.0	4.9	4.7	4.6	4.5	4.2	4.1	OFF

The normal load capacity of the heater are 3500 watts or 5 A. The heater operated in 8 weeks with off on Sunday. The performance of heater was decrease in a week at 0.2 A. This is much better compare the old system that have decrease in 0.5 A a week. The heater was broken, if the load capacity reduce below 4 A. So, with this new system, the heater that was broken after 8 weeks are 30%.

4.0 CONCLUSION

The accuracy of temperature heater was stable at seting point. The gain of PID control also affect to performance of the heater. With the smallest PID value set in Kp = 2000, Ki = 6, and Kd = 100, the heater can be made faster stable at the value set. The value of an impact on the work of on-off heater when its value has reached the value set 95⁰C. Heater work in 3 minutes and be off in 5 minutes - 7 minutes.

With such results, the use of heater with PID on-off system that is used 24 hours continuously for 2 weeks full time off the heater for 24 hours only will make the heater last for approximately 1.5 months to 2 months of usage. The heater will be damaged at current values below 4 amperes.

The new system was improve the lifetime of the heater until 8 weeks and the performance only reduce 0.2 A in a week.

Acknowledgement

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