The Annual Conference on Management and Information Technology (ACMIT) 2015

Automation of Process Control in Chemical Plant

Agus Sugiarta, Houtman P Siregar, Dedy Loebis

“Department of Mechanical Engineering, Faculty of Engineering and Information Technology
Swiss German University, EduTown BSD City, Tangerang 15820, Indonesia
Email: agus.sugiarta@student.sgu.ac.id

Abstract

Automation of process control in chemical plant is an inspiring application field of mechatronic engineering. In order to understand the complexity of the automation and its application require knowledges of chemical engineering, mechatronic and other numerous interconnected studies.

The background of this paper is an inherent problem of overheating due to lack of level control system. The objective of this research is to control the dynamic process of desired level more tightly which is able to stabilize raw material supply into the chemical plant system.

The chemical plant is operated within a wide range of feed compositions and flow rates which make the process control become difficult. This research uses modelling for efficiency reason and analyzes the model by PID control algorithm along with its simulations by using Matlab.

Keywords: Automation; PID; Process Control

1. Introduction

Automation of process control in chemical plant face many challenges on how to ensure the rapid real time sampling and how to ensure that the correct data transmissions so the system could be controlled accurately. It is difficult due to their non linear, time varying behaviour and poor quality of available measurement [1].

It is also essential to know and include the desired output to realize the superiority of control performance in term of higher accuracy and provide a robust control performance. The controller that is being introduced focus on PID algorithm with variable gains. By manipulating some variables, the controller would be able to take control of the dynamic behaviour of process control in the chemical plant.

The proportional integral and derivative (PID) controller has only 3 parameters but without a systematic procedure, it is not easy to find good values for them [2].

2. Literature Review

In chemical plant, liquid such as acid is used in various process. The amount of such liquid stored can be found by measuring the level in the storage tank. The controller should be able to handle a bulk of quantity of material therefore it should be studied and verified well before its implementation.

2.1. Sensor and Actuator

Acid chemical is a corrosive material therefore the selection of sensor is crucial to the overall control system. The indirect method of capacitance sensor is recommended. An insulated electrode act as one plate of capacitor and the tank wall acts as the other plate. The measurement work is based on change of capacitance made by applying RF signal between conductive probe and the vessel wall. And converted into signals by transducer. The potential difference across sensor at constant current is the measure of level. The potential difference then amplified by an operational amplifier to give a voltage which can directly drive a display [3].
Beside the sensor, the selection of an appropriate actuator is also crucial to the overall control system. A motorized valve that is coated by teflon with butterfly design is recommended since tight sealing is one of the main concern in the operation of the plant. Its design with several levels of shaft safety sealing could prevent leakage problems.

2.2. Controller

In order to get an accurate control, a simple turn On/Off will not work well especially when controlling large volumes of liquid chemical as they tend to introduce an oscillation of level around the set-point in a sinusoidal pattern.

Automatic control have variety of forms like an open loop, a single close loop and a cascade control. Beside that, there are many control methods such as Sequential Control, Relay Logic Control, PID, Fuzzy Control and Model Predictive Control. So far in industrial application, the PID control of single close loop is applied as the most applicable control.

As for PID controller, there are digital PID and analog PID. The digital PID is more convenient to use because it gives more accurate control than analog PID controller [4]. PID controllers optimize close loop performance and improve robustness in the varying time delay system by comparing the measured actual value with respect to its set point, and manipulating of the process in a way that will hold the variable at its set point when a disturbance changes the process.

The variable being adjusted is called the manipulated variable which is equal to the output. The output will be changed in response to change in measurement or set-point.

![PID Response Signal](image)

Fig 1. PID Response Signal
3. Research Flowchart

Step 1. The research started from modelling of the level system. By knowing the mathematical model and do the laplace transform, it would be able to find the transfer function of the system in first or second order. In this step, the research started to find out step response of an open loop. The gain of this step is to have mathematical model in s-domain.

Step 2. The research then continued by checking the response of the control system using P controller and then using the combination of PD, PI and PID in order to find the best step response. The expected output from this second step were optimum controller parameters and well tuned PID controller or else the PID tuning should be repeated again.
4. Result and Discussion

4.1. Modelling

\[ \frac{dh}{dt} = Q_{\text{in}} - Q_{\text{out}} \]  

(1)

This equation describes the system behaviour and it is smooth enough to be linearized. It is a differential equation relating input flow rate $Q_{\text{in}}$ to the output level $h$ where :

\[ M \ddot{x} + c \dot{x} + kx = F \]  

(2)

Fig 3. Level Model in Storage Tank

The model of behaviour of the tank is necessary so the changes in level due to changes in flow conditions can be predicted. $Q_{\text{in}}$ and $Q_{\text{out}}$ [m$^3$/min$^{-1}$] are the volumetric flows in and out of the tank. The level in the tank is given by $h$ [m]. The flows are volumetric so it needs density term to convert from volume units to mass units. The cross-sectional area (A) of the tank must be known, so that we can determine the volume in the tank. Since there is no heating effect, the density can be assumed constant and since the tank is cylindrical, it has constant cross-sectional area [5].

Fig 4. Level Analog to Mechanical
4.2. Analysis by Matlab

In case of 2lt with the specific gravity known 2.0 so M = 4 kg and also are known that c = 20 Nms, k = 30 N/m and F = 1 N, then the transfer function of an open loop would be:

\[
\frac{1}{(4s^2 + 20s + 30)}
\]  

Fig 5. Open Loop Step Response

The step response of an open-loop with the gain 0.035 is quite large indeed. The rise time which is about 4 seconds and settling time 6 seconds are not good enough and too high especially for application in the industrial scale.

It is necessary to do tuning by introducing the close loop control and then start with using only P controller. For Kp = 250, the transfer function:

\[
\frac{250}{30s + 200}
\]  

Fig 6. Step Response of P Controller
By introducing P controller, it is able to reduce the rise time significantly but the steady state error is still quite big so it is necessary to try and add another controller to get the benefit of the combination of each controller.

By using PD controller at $K_p = 240$ and $K_d = 10$, the transfer function:

$$\frac{10s + 240}{40s + 270}$$

Fig 7. Step Response of PD Controller

PD controller turns out is not giving a significant effect as expected yet. Therefore it is necessary to introduce another controller which is the integral controller that will give double effect. For PI controller at $K_p = 40$ and $Ki = 60$, the transfer function:

$$\frac{40s + 60}{30s^2 + 70s + 60}$$

Fig 8. Step Response of PI Controller

From the step response, it is clear that the Integral controller is able to eliminate the steady-state error. Finally the PID controller is being introduced and after several trial and errors, got the parameters at $K_p = 600$, $Ki = 500$ and $Kd = 100$, and the transfer function is:
By using PID controller, it is obtained the desired response with the best rise time, no overshoot and no steady-state error.

By using PID controller, it is obtained the desired response with the best rise time, no overshoot and no steady-state error.

<table>
<thead>
<tr>
<th>Table 1. Parameter</th>
<th>Kp</th>
<th>Kd</th>
<th>Ki</th>
<th>TF</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>250</td>
<td></td>
<td></td>
<td>$\frac{250}{30s + 280}$</td>
</tr>
<tr>
<td>PD</td>
<td>240</td>
<td>10</td>
<td></td>
<td>$\frac{10s + 240}{40s + 270}$</td>
</tr>
<tr>
<td>PI</td>
<td>40</td>
<td></td>
<td>60</td>
<td>$\frac{40s + 60}{30s^2 + 70s + 60}$</td>
</tr>
<tr>
<td>PID</td>
<td>600</td>
<td>500</td>
<td>100</td>
<td>$\frac{100s^2 + 600s + 500}{130s^2 + 630s + 500}$</td>
</tr>
</tbody>
</table>

5. Conclusion and Recommendation

After several trials with P controller and the combination of PD, PI and PID, the best result of output response is obtained by PID controller. The controller could be well tuned because mathematical models in s-domain are available.

It is recommended, when necessary, to study further on other algorithm such as fuzzy logic to get a higher control accuracy.

References

[2] Sigurd Skogestad, Simple Analytic Rules for Model Reduction and PID Controller, Department of Chemical Engineering, Norway University of Science and Technology.