Design and Implementation of Multi IMC-PID for A Pressure Plant

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Abstract: - This paper studies Internal Model Control (IMC) and its structure and applications in process. By using the capability of IMC we obtained PID coefficients and designed the IMC-PID controller. Then the IMC-PID is used in multi controller structure to control the pressure plant (RT532).

Key-Words: Internal Model Control (IMC), IMC-PID, Process Control, System Identification, Process Modeling, RT532 Pressure Plant.

1 Introduction

Considering developments of productive automatic industry and advanced industrial processes, it is necessary to be aware of automation methods, and industrial process control.

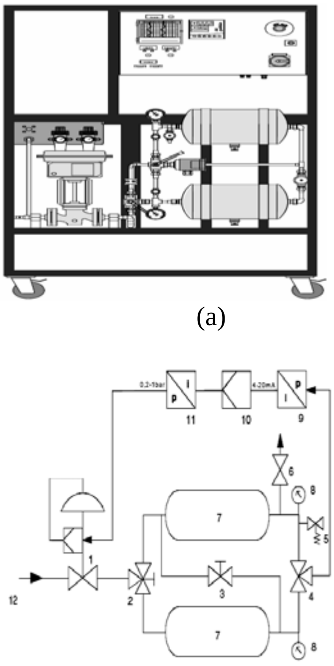
Measurement industry and control of physical quantities such as pressure, liquid flow, liquid height level and temperature are important. As we know, the aim of control and designing a controller is system's stability, tracking the entry, disturbance rejection, noise reduction and being stable against changes in system parameters [2].

Internal model control (IMC) has been considered by experts and researchers in different areas. One of the strength points of this controller is its applicable role in industry [2]. The advantages of this controller are its simple design and the more important, its guaranteed stability as a close loop controller [1, 2]. In this paper the capability of multi controller of IMC on pressure plant is considered. The aim is to control the internal pressure plant tracks several set-points and disturbance from output value of reservoir should be rejected.

In Section 2, the pressure plant is introduced. In Section 3, the design method of IMC-PID and its proof is expressed. Implementation and result analysis of output of pressure plant in order to reject the disturbance is represented in Section 4. Finally Section 5 briefly summarizes the material presented in this paper.

2 Pressure Control Pilot Plant

The test plant in this paper is pressure control set called RT532, which is equipment for engineering education produced by GUNT Company [6]. Fig. 1 illustrates the RT532 and its P&ID diagram.



(a)

(b)

Fig.1: (a) RT532 (b) RT532's P&ID schematic

2.1 System configuration and operation

According to the P&ID schematic in Fig. 1(b), after #12 which is air entrance value from compressor controlling valve #1 located, there is a pneumatic valve that has a converter on it on order to convert received electrical signal (voltage) from controller to proportionality pressure signal between 0.2 and 1 [6].

According to this parameter the valve will be opened or closed. Air flow is passing through controlling valve, enters triple valve #2, which is considering its location (vertical or horizontal), the air flow enters to lower or upper capsule, #7, [6].

#3 is the connection valve between the capsules. There is two-condition valve, #4, beside the pressure sensor for measure the capsule's pressure based on valve position. It is possible to empty upper capsule by the output valve of upper capsule, #6. Also it can be used as disturbance entry. This valve is permeated which cause a little error in the valve identifying and controlling. There is a pressure sensor beside capsules for measuring the capsule's pressure and send the signals to controlling board, #9, by receiving the order from controller and creating adequate pressure signal, it identifies how much valve to be opened or closed, #11. All controlling orders to system and measurements are done by a controller, #10, called JUMO. It controls all entrances and discharging. Moreover, it is possible to connect to Profibus that can transmit all entrances and discharging to a computer [6].

2.2 Identifying and modeling of pressure system

Modeling of industrial process is the main key to identifying these systems and designing suitable controller for them. It is possible to specify the system dynamic by system response to step, impulse, ramp or any signals [3, 4, and 5]. In this paper we use the step input. By using the normalized method of output, we can estimate simple or complex models that are the First-order model with delay (three-parameter model) is used [5]:

$$G(s)=\frac{k}{\tau s+1}e^{-Ls} \qquad (1)$$

The aim is to identify the upper pressure capsule with first-order model with delay in several set-points. When the output valve is open 30%, 40% and 60% we modeled the system in 40 and 70 kilo Pascal set-points. Obtained models from identification are in Table 1.

As we see in table 1, the first order model with delay has good fitness with the output of pressure system.

3 Using IMC to Design A PID Controller

One of the most useful controllers in industry is PID controllers [2]. It is interesting that the coefficients of this controller is not easy to set. Here, instead of identifying its structure and then set its parameters to extract optimum result, we use another method. First, as a default, we define expected final conditions and controlling problems with its component. Then to achieve favorite controller with its parameter, we solve mentioned problem. IMC structure is adequate framework to achieve the aim of system [1, 2]. All models in industry gathered in [4], that IMC will be leaded to PID controller for all models. Now the changing function of PID controller from IMC is prepared to put coefficient in the table and is calculated through (2) [4]:

Table 1: Transfer functions and their fitness

Valve Position	Set Point (KP)	Transfer Function			Fitness (%)
		k	τ	L	
30%	40	2.37	46.618	-4	94.22
	70	3.73	85.477	-4	83.76
45%	40	2.80	50.635	-4	85.87
	70	4.43	43.171	-4	91.56
70%	40	3.15	34.274	-4	85.61
	70	4.81	23.201	-4	90.51

$$G(s)=(\frac{k_C}{\tau_F s+1})(1+\frac{1}{\tau_I s}+\tau_D s) \qquad (2)$$

In initial pressure plant, system in several set-points with first order model with delay is approximated as below [1, 5]:

$$G(s)=\frac{k}{\tau s+1}e^{-sL} \qquad (3)$$

Using Pade approximation for delay [1]:

$$e^{-sL}=\frac{1-\frac{1}{2}sL}{1+\frac{1}{2}sL} \qquad (4)$$

We have:

$$G(s) = \frac{k}{\tau s + 1} * \frac{1 - \frac{1}{2} sL}{1 + \frac{1}{2} sL} \qquad (5)$$

$$G(s) = \frac{k(1 - \frac{1}{2} sL)}{\frac{1}{2} \tau L s^2 + (\tau + \frac{1}{2} L)s + 1} \qquad (6)$$

By changing parameters of (6), we got similar formula in row F of page 116-117 in [4], so we have:

$$\frac{1}{2} L = \beta \qquad (7)$$

$$\frac{1}{2} \tau L = T^2 \qquad (8)$$

$$\tau + \frac{1}{2} L = 2\zeta T \qquad (9)$$

$$\frac{\tau}{2} L = \varepsilon \qquad (10)$$

Where ε is the time constant of close-loop system. Whereas band-width for close-loop system is seldom more than band-width for open-loop system, so we have $\varepsilon \rangle \tau/10$. In this paper we consider $\varepsilon \rangle \tau/2$ [4].

Now by changing mentioned variables, the transfer function will become:

$$G(s) = \frac{k(1 - \beta s)}{T^2 s^2 + 2\zeta T s + 1} \qquad (11)$$

Considering to format of controllers, we get the coefficients of IMC-PID controllers are as (13-16):

$$G(s) = (\frac{k_C}{\tau_F s + 1})(1 + \frac{1}{\tau_I s} + \tau_D s) \qquad (12)$$

Where

$$k_C k = \frac{2\zeta T}{2\beta + \varepsilon} \qquad (13)$$

$$\tau_I = 2\zeta T \qquad (14)$$

$$\tau_D = \frac{T}{2\zeta} \qquad (15)$$

$$\tau_F = \frac{\beta\varepsilon}{2\beta + \varepsilon} \qquad (16)$$

4 Design and Implementation of Multi Controller IMC-PID for Pressure Plant

The pressure system that has been used in this paper is a nonlinear system and our aim is control the inner pressure of reservoir in different points. As we see there are different models for different set-points. So we use multi controller method and put two models related to the condition of discharging valve with related controller in its structure. While input of pressure plan (controlling signal) and two achieved models are same, the pressure plant's output is compared with each models and the model which is similar to the system model is selected. Then the designed controller for selected model is located in the feedback loop before pressure plant and control the system. The structure of multi IMC-PID for two models is shown in Fig. 2.

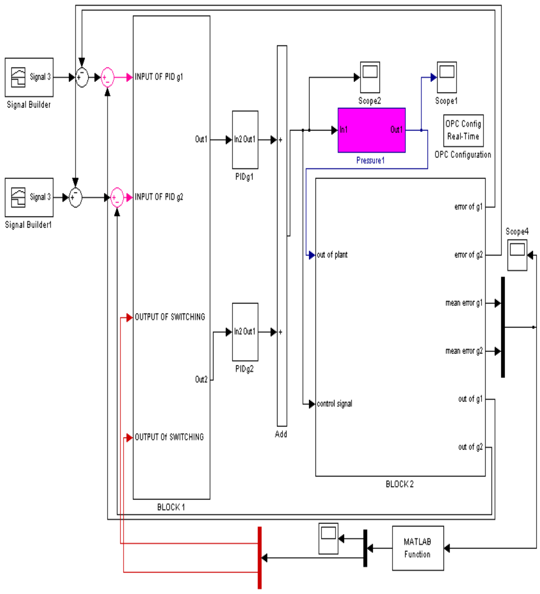


Fig. 2: Block diagram of multi IMC-PID

In IMC structure, the sufficient condition for the stability of the whole system depends on the controller and plant stability [1, 2]. Since pressure system and PID controller are stable, it causes the whole feedback stable.

4.1 Disturbance rejection

We use IMC-PID controller to neutralize disturbance effects. Changing the condition of discharging valve is disturbance in pressure system. By locating six achieved models in the multi controller structure, we want to control widespread of pressure plant in different set-points. It means that plant's output track several work points, whereas the changes of output valve from 30% to 60% is too much.

We set output valve to 30%, when plant's output track 40 Kilo Pascal and becomes steady state, then we set the output valve to 45% and changed the set-point and after getting to steady state, it changed to 60%, so we produce the disturbance. The structure of multi IMC-

PID gives a favorite output by choosing a suitable controller [1, 2].

Fig. 3 shows the output of the pressure plant. From Fig. 3 we see that plant's output tracks several set-points while disturbance is rejected. Controlling signal and the switching between models are shown in Fig. 4 and 5 respectively. As we induct from figures, when multi IMC controller is used, the output has favorite static and dynamic behavior.

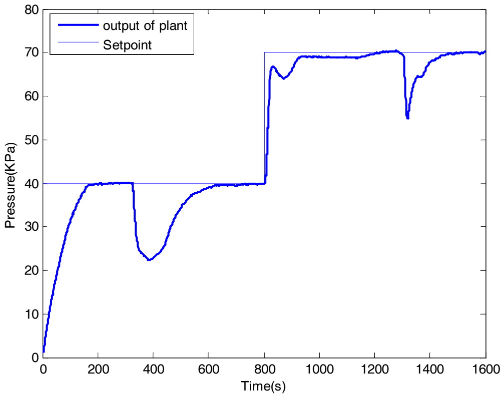


Fig. 3: Output of pressure plant

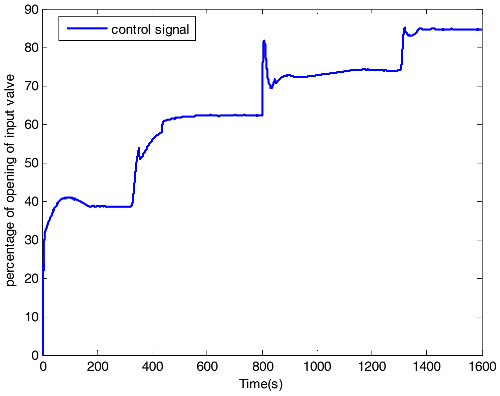


Fig. 4: Controlling signal

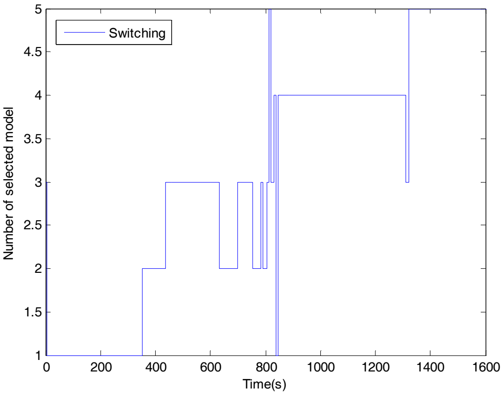


Fig. 5: Switching between models

5 Conclusion

In this paper IMC is used for control of RT532 pressure pilot plant. The system was modeled as First-order system with time delay, and the parameters are identified, then multi IMC-PID is applied to control. The obtained results show that the IMC-PID controller guarantees stability of the plant and disturbance rejection.

6 Acknowledgements

The authors would like to thank Mr. Siavash Fakhimi and Mr. Hamidreza Nourzadeh for support of this work.

References:

[1] Ming T. Tham, Internal Model Control, A part of a set of lectures on Introduction to Robust Control, *A Treatise on Electricity and Magnetism*, Vol.2, 2002, pp. 68-73.

[2] M. Shamsuzzoha, Moonyong Lee*Jietae Lee, IMC-PID Controller Tuning for Improved Disturbance Rejection of Unstable Time Delay Processes, *Theories and Applications of Chem. Eng*, Vol.11, No.2, 2005.

[3] Y. Lee, J. Lee, S. Park, PID Controller Tuning for Integrating and Unstable Processes with time delay, *Chem. Eng. Sci*, Vol.55, 2000, pp. 3481-3493.

[4] M. Morari, E. Zafiriou, *Robust Process Control*, Prentice Hall, 1989.

[5] K.J. Astrom, T. Hagglund, *PID Controllers: Theory, Design and Tuning*, Instrument Society of America, Research Triangle Park, North Carolina, 1989.

[6] G.U.N.T. Geratebau GmbH, Postfach 1125, 22881 Barsbuettel, http://www.gunt.de.