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Real Time Implementation of Model Reference Controller in a Spherical Tank Process

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Abstract: In non linear process, control of process parameters is one of the important problems particularly, long dead time and unstable process. In this paper, a Model Reference Controller is implemented to improve the control performance for a spherical tank level process .The control method is combined with IMC and PD feedback where PD feedback is designed by Maclaurin series. The process dynamics are described by the transfer function model by utilizing the step test technique. Experimental results are furnished to illustrate the effectiveness of the Model Reference controller.

1. INTRODUCTION

Non linearprocesses have different control issues like large dead time, uncertain and time varying parameters. The robust controller is tuned to give better performance to model uncertainty. Because of the inherent nonlinearity, most of the chemical process industries are in need of robust control techniques. A Model Driven concept is projected by K.Hidenori as an alternative control system (Y.M. Zhao, 2011). This concept proposes using a perfect plant model as a block of a control system to compare the error of the actual plant against that of the ideal plant. A Model Driven PID control system designed by Masanori Yukitomo (Masanori Yukitomo, 2002) joins with Modern Driven Control system with a PD feedback and Internal-Model Control (IMC). Results surveyed in the chemical process especially in the temperature controlled process, drum level control loop of chemical process, Boiler and Turbine operation (Masanori Yukitomo,2002) by the use of Model Driven Reference control.In this paper, the Model Reference control system is designed and implemented in the real time spherical tank non linear process. The Model reference control system is stabilized with unstable process by adding PD feedback control loop. The main controller consists of gain block, IMC block and the process model block.

The paper is organized as follows: Section 2 summarizes the real time implementation of Model Reference controller in spherical tank process. In Section 3 describes about Model Reference controller. Section 4 illustrates the design approach of Model Reference controller. Section 5 describes the result and discussion. Summarized all work in section 6.

2. Real Time Implementation

The experimental set up of the Spherical Tank system is shown in Figure 1. The set up consists of a mild steel spherical column of 50cm diameter at a slant height of 50cm, opened to the atmosphere at the top. The rotameter and Electro pneumatic positioner are mounted in order to measure the flow rate and level in the tank. The level is sensed by transmitter, which is given to the interface Card VMAT01. The current output signal (4-20 mA) from the sensor is processed by interface card and the corresponding digital value is read back as level value and compared to the input set point. The control algorithm gives suitable control signal employed for actuation of the control valve that is normally open with C_v of 5.0. Technical Specifications of Experimental Setup is explained in detail in Table 1

2.1 Black Box Modeling parameters (Nithya et,al.,2008, Sathishbabu and Bhaba,2012) and Controller settings identification

Initially the level in the tank is maintained at steady state of 40% (12 cm) of the total height. A step size of 5% in DAC output is given to the system and the variation in level in percentage is recorded against time until a new steady state is attained. From the experimental data the FOPTD model parameters such as process gain (K_p), time delay (t_d) and time constant (τ_p) of the level process are determined. The identified transfer function model for the Level System is given as

$$G(s) = \frac{2}{750s+1} e^{-180s} \qquad (5)$$

The experimental data are approximated to be a FOPDT model.

Table.1.Technical Specifications of Experimental Setup

Spherical Tank	Material :Stainless Steel Diameter - 50 cm, Volume : 102 liters
Storage Tank	Material :Stainless Steel , Volume : 48 liters
Differential Pressure Transmitter	Type Capacitance, Range (2.5 - 250)mbar, Output (4 - 20)mA Siemens make
Pump	Centrifugal 0.5 HP
Control valve	Size ¼" Pneumatic actuated" Type: Air to close Input (3 - 15) psi
Rotameter	Range (0 - 18) lpm
Air regulator	Size 1/4" BSP Range (0 - 2.2)bar
I/P converter	Input (4 - 20) mA Output (0.2 - 1) bar
Pressure gauge	Range (0 - 30) psi Range (0 - 100)psi

2.2 Controller parameters for conventional PI and IMC PI (J.B.Ziegler and N. B. Nichols,1942)

Based on the above model equation (5), the parameters of the PI mode based on the Z-N and IMC are calculated and summarized in the Table 2

Table.2. Parameter values for conventional pi and imc pi

CONTROLLERS	$\mathbf{K_C}$	$\mathbf{T_I}$
CONVENTIONAL PI	1.67	582.75
IMC PI	1.09	765

3. Description of Model Reference controller

Here the main controller consists of IMC Gain, IMC block and Process Model block. The first order delay with dead time model is used in the process model block. Moreover λ, τ_c tuning parameter and closed loop time constant are also referred. The Model Reference control system using the PD feedback is capable of stabilizing with wide process, regulating quickly for disturbance and tracking quickly to the change of set point. The schematic diagram of proposed PID control system is given below

4. Design Approach for Model Reference controller (S.M. Jagdish , S.Sathishbabu,2012)

The Model Reference control system can be designed with the following steps. Many processes are expressed by the first order with dead-time model or the integral with dead-time model. The denominator polynomial form can be expressed by using the Maclaurin series expansion of dead time.

G(s) is the given function

By using Maclaurin series expansion

$$G(s) = \frac{1}{g_0+g_1s+g_2s^2+\cdots} \qquad (1)$$

g_i(i=1, 2, 3…) are the i^{th} order parameter of denominator polynomial.

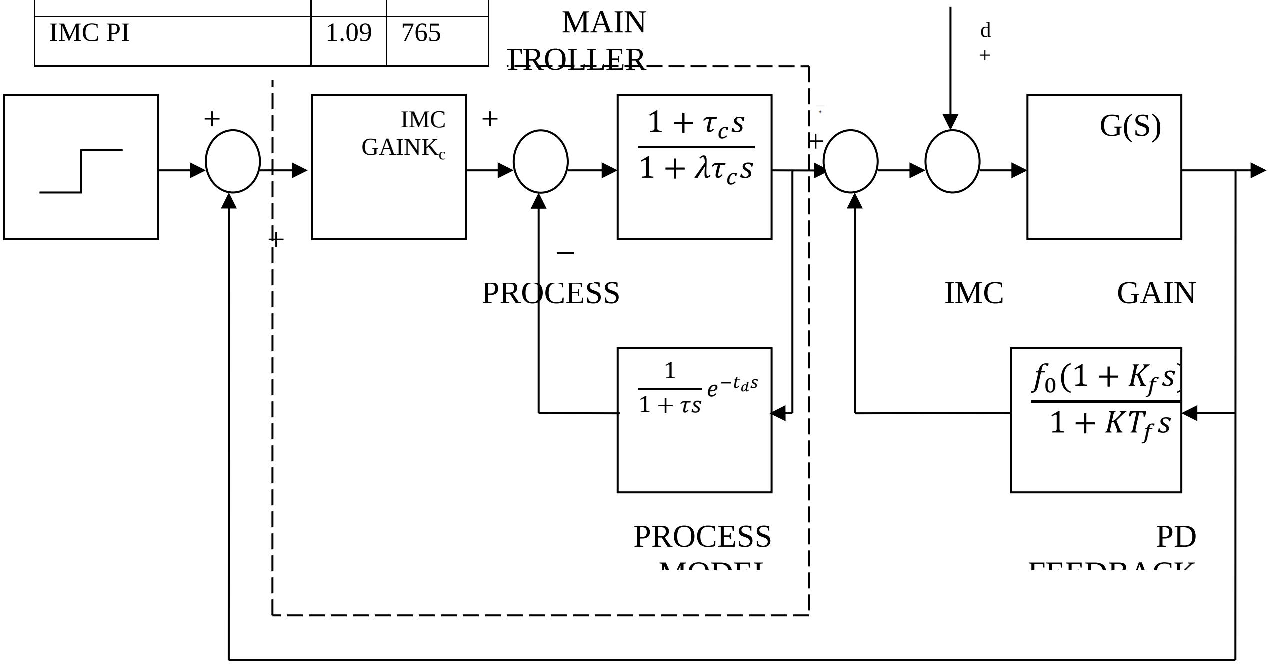

Figure 2. Model Reference PID Control System

4.1 PD Feedback Compensation

The polynomial series representation (i.e. Maclaurin series) of any infinitely differentiable function P(s) whose value, and the values of all of its derivative at s=0is given by

$$G(s) = G(0) + G'(0)s + \frac{G''(0)}{2!}s^2 + \frac{G'''(0)}{3!}s^3 + \cdots \qquad (2)$$

Where

$$G(0) = g_0 \qquad (3)$$

$$G'(0) = g_1 \qquad (4)$$

$$G''(0) = g_2 \qquad (5)$$

$$G'''(0) = g_3 \qquad (6)$$

and for PD feedback compensation

$$\sigma = \frac{\beta_2 g_3}{\beta_3 g_2} \qquad (7)$$

$$f_0 = \frac{g_2}{\beta_2 \sigma^2} - g_0 \qquad (8)$$

$$f_1 = (g_0 + f_0)\sigma - g_1 \qquad (9)$$

Where

σ =Response time of the loop

β_2 *and* β_3 are response shape factor

Now the values of the K_f *and* T_f can be easily derived from the above values as

$$K_f = \frac{f_1}{f_0} \qquad (10)$$

Now from the f_0 *and* K_f values the PD feedback compensation block can be designed as

$$PD\ feedback = \frac{f_0(1+K_f s)}{1+KK_f s} \qquad (11)$$

Where the value of K is usually from the value 0.01

Table 4. Parameter values for model reference controller

NAME	**PARAMETER**	**VALUES**
IMC Gain	K_c	0.7
Tuning Parameter	λ	0.1
Response Shape Factor	β2	0.38
	β3	0.05
PD Feedback block	f_o	0.1
	K_f	100
	K	0.01

5. RESULTS AND DISCUSSION

The diagram of the Model Reference controller shown in figure 2. For fast and overshoot response, the response shaping factor β_2 and β_3 values are chosen accordingly. The response time σ, f_0, K_f is obtained using the PD feedback compensation based on Maclaurin series compensation as discussed in section 4 are tabulated in Table 4. Real time runs for a Spherical tank liquid level system with Model Reference control loop, IMC control loop and conventional PID control loop are carried out by means of ±5 step change and their output responses are recorded in figure 3 to 8. In all the cases the normal operating point is 40% of the total output is maintained. Performance analysis is done for servo responses based on ISE and settling time and their values are tabulated in the table 5. From the table it is clear that the Model Reference controller gives good performance than the conventional PID controller and IMC.

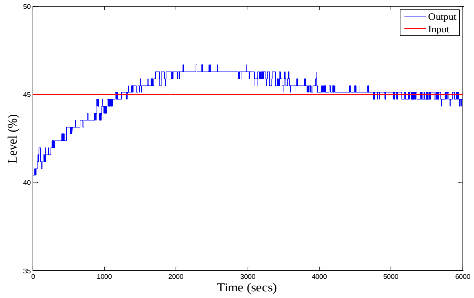

Figure 3 Real time response of Model Reference controller (+5)

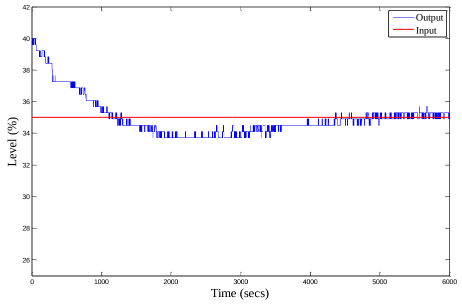

Figure 4 Real Time Response of Model Reference Controller (-5)

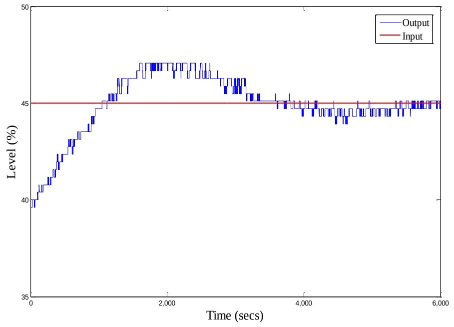

Figure 5 Real Time response of conventional controller (+5)

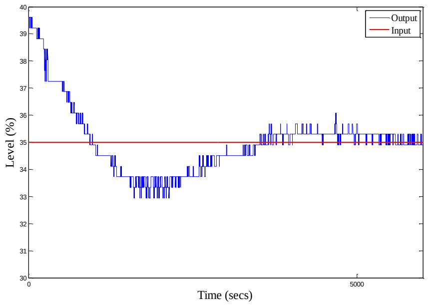

Figure 6 Real Time response of conventional controller (-5)

Table 5. Performance analysis of spherical tank level process

CONTROLLERS	**ISE**		**SETTLING TIME**	
	+5	**-5**	**+5**	**-5**
MODEL REFERENCE	13460	9765	4800	4500
PID	15910	9883	5700	5500
IMC	17840	12380	7200	5800

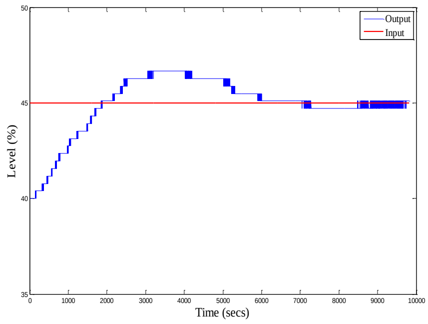

Figure 7 Real Time response of IMC (+5)

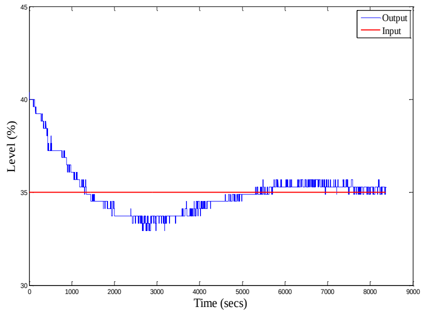

Figure 8 Real Time response of IMC (-5)

6 CONCLUSION

In this paper, a Model Reference controller is designed and implemented in real time Spherical tank level process using V-MAT module. Identification and controller design shows that the above method is effective in using the low cost data acquisition system. Experimental results show that the response is smooth for both set point for a Model Reference controller compared with conventional controller. The Model Reference controller exhibits a very minimum overshoot with faster settling time. This is also validated by the values of performance indices for ISE and settling time. It is concluded that Model Reference is suited to maintain the level in a tank.

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