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Research Article

Real Time Implementation of Model based Controller for a Spherical Tank

K.Hari Krishna[a*], J Satheesh Kumar[b], Mahaboob Shaik[c]

[a]Department of Electronics and Instrumentation, CUTM, Paralakhemundi, odisha, India
[b]Department of Electronics and Instrumentation, Karunya University, Coimbatore, India
[c]Department of Electronics and Instrumentation, MJCET, Hyderabad

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Abstract

Control of process parameters is one of the important problems in process industry. The process considered for modeling is spherical tank liquid level system. Control of liquid level in a spherical tank is nonlinear due to the variation in the area of cross section of the level system with change in shape. Nonlinear process control is a difficult task in process Industries. Spherical tank is a nonlinear system due to its variation in the area of cross section. In this project the modeling of Spherical tank system is done. The nonlinear parameters are linearised by using the Taylor-series. The controller is designed using Model Reference Adaptive Controller based on MIT rule. Adaptive Controller for Spherical tank system is simulated in LabVIEW environment. Real time implementation of model based controller for spherical tank is designed using LabVIEW control design toolkit.

Keywords: *Mrac, Labview, Nonlinear System, Data Accquistion Sytem,Spherical Tank*

1. Introduction

Chemical processes presents many challenging control problems due to their nonlinear dynamic behavior, uncertain and time varying parameters, constraints on manipulated variable, interaction between manipulated and controlled variables, unmeasured and frequent disturbances, dead time on input and measurements. Because of the nonlinearity, most of the chemical process industries are in need of advanced control techniques. Spherical tanks find wide application in gas plants. Control of a level in a spherical tank is important, because the change in shape gives rise to the nonlinearity.

Model based control was developed primarily for processes having a pronounced time delay, the intent of being matched by the process delay with one in the control system.

Model based control is very popular nowadays due to the ability of such controllers to handle process with dead time effectively. One important type of model based control is Model Reference Adaptive Control (MRAC), which has the combined advantage of both open and closed systems. For a nonlinear process MRAC based control outperforms than the conventional PI tuning.

A non-linear process, the spherical tank level process whose parameters vary with respect to the process variable is considered. At a fixed outlet flow rate the system is controlled and maintained at the desired level. The time constant and gain are the important variables which vary as a function of level in the chosen process.

2. Mathematical modeling

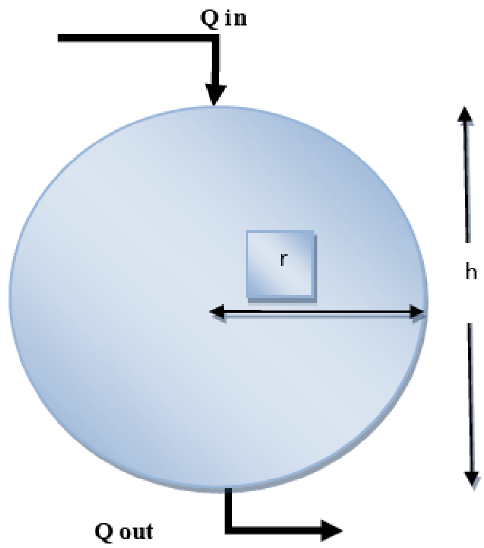

Figure 1. Spherical Tank Level Process

Using the law of conservation of mass,
Rate of accumulation of mass in the tank = Rate of mass flow in – Rate of mass flow out

$$\frac{d(\rho v)}{dt} = \rho_1 q - \rho_2 q_0 \quad (1)$$

*Corresponding author: K.Hari Krishna

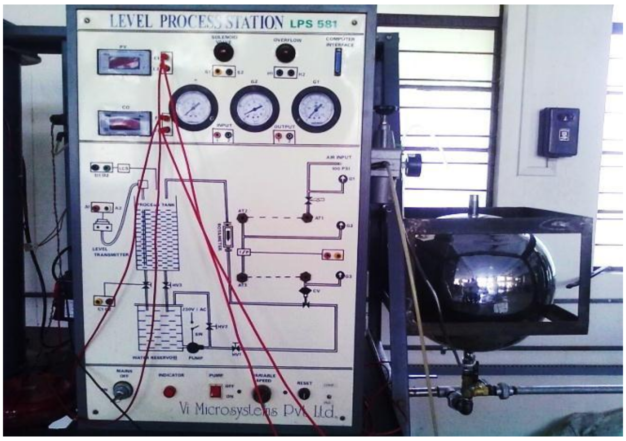

Figure 2. Hardware setup for spherical tank level process.

ρ	= density of the liquid in the system	Kg/lt
ρ_1	= density of the liquid in the inlet stream	Kg/lt
ρ_2	= density of the liquid in the outlet stream	Kg/lt
V	= total volume of the system	m^3/sec
q	= volumetric flow rate of the inlet stream	LPH
q_0	= volumetric flow rate of the outlet stream	LPH

$$\frac{dv}{dt} = q - q_0 \quad (2)$$

$$q_0 = c\sqrt{h} \quad (3)$$

Where '*c*' is the valve constant. Therefore the equation-2

$$R_t = \frac{2\sqrt{h_s}}{c} \quad (4)$$

volume of sphere $V = \frac{4}{3}\pi r^3$ And can be rearranged into a standard form of the first order system to give,

$$\frac{H(s)}{Q(s)} = \frac{R_t}{(\tau s+1)} \quad (5)$$

Where $\tau = \frac{R_t}{2}\pi {h_s}^2$

Thus the equation – (5) gives the model of the system.

Table 1: Transfer Function model parameters

Level Range	R_t (Gain)	τ
(*cm*)		(Time Constant in sec)
7	0.828	63.69
10	0.9897	155.38
20	1.3997	879.01

Transfer function parameters

The valve constant c = 6.3836

We know that

$$R_t = \frac{2\sqrt{h_s}}{c} \qquad \tau = \frac{R_t}{2}\pi {h_s}^2$$

With all the above information the following calculation is obtained

The tabulation shown above represents piece-wise models around four operating points as shown in the level ranges. The transfer function model parameters are found for all the regions and the controller parameters are tuned further.

$$\frac{H(s)}{Q(s)} = \frac{0.9897}{(155.38s+1)}$$

This is the Transfer Function Model of the process tank system.

3. Model reference adaptive control

3.1 Model Reference Adaptive System (MRAS)

MRAS or model reference adaptive system that uses Model Reference Adaptive Control (MRAC) is an adaptive system that makes explicit use of such models for identification or control purposes. In MRAC, a good understanding of the plant and the performance requirements it has to meet allow the designer to come up with a model, referred to as reference model, that describes the desired I/O properties of the closed loop plant (Ioannou and Sun, 1996). The basic structure of the MRAC is shown in Figure 5.1 on the next page. The reference model is chosen to generate the desired trajectory, Y_m , that the plant Output Y_p has to follow.

The tracking error, which is generated by comparing the plant output with the reference model output, represents the deviation of the plant output from the desired trajectory. The closed loop plant is made up of an ordinary feedback control law that contains the plant and a controller and an adjustment mechanism that generates the controller parameter estimates on-line.

3.2 MRAC Concepts

The block diagram in Fig.3. Shows the structure of a model reference adaptive control (MRAC) system that is composed of process, controller, reference model and adjustment mechanism block.

The model reference adaptive control (MRAC) technique is based on information ym, yp , U, and Uc is used for devising a controller. The adjustment mechanism automatically adjusts controller parameters so that the behavior of the closed –loop control plant output (yp) closely follows that (ym) of the reference model. Parameters and structure of reference model are specificities on the base of requirements of control performance. The adjustment mechanism of MRAC system constructed by adaptive control rule called MIT rule which performs the algorithms as following

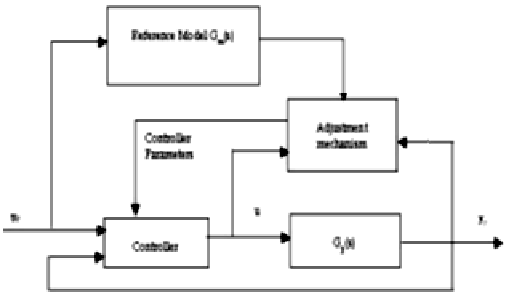

Fig.3. Block diagram of model reference adaptive control (MRAC) system

Tracking error : $e = y_{plant} - y_{model}$

The cost function: $J(\theta) = \frac{1}{2} e^2(\theta)$

MIT Rule says that the time rate of change of θ is proportional to negative gradient of J. That is

Controller law: $u = \theta u_c$

Update rule: $\frac{d\theta}{dt} = -\gamma \frac{\partial J}{\partial \theta} = -\gamma e \frac{\partial e}{\partial \theta}$

Tuning parameter is γ
Adjustable parameter is θ
Control signal is u and command signal is u_c
$\theta = \frac{k}{k_0}$

Where e denotes the model error and θ is the controller parameter vector. The components of $\frac{\partial e}{\partial \theta}$ are the sensitivity derivatives of the error with respect to θ .The parameter γ is known as adaptation gain. The MIT rule is a gradient scheme that aims to minimize the squared model cost function.

4. Results and Discussions

The Block diagram of MRAC for adjustment of a feed forward gain based on the MIT rule is shown below. The block diagram and output response of MRAC controller in real time implementation is observed for different set points. The reference model transfer function and plant transfer functions are included in the block diagram. The output response is observed in the scope.

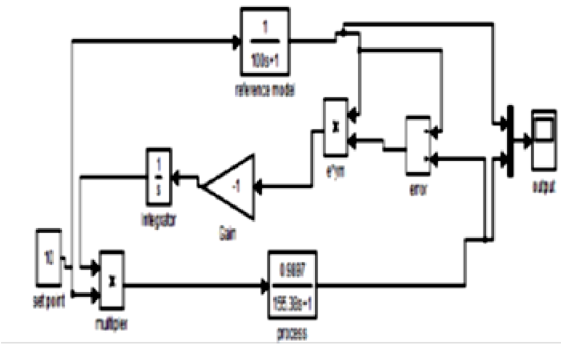

Fig.4 Block Diagram Of MRAC Feed Forward Gain.

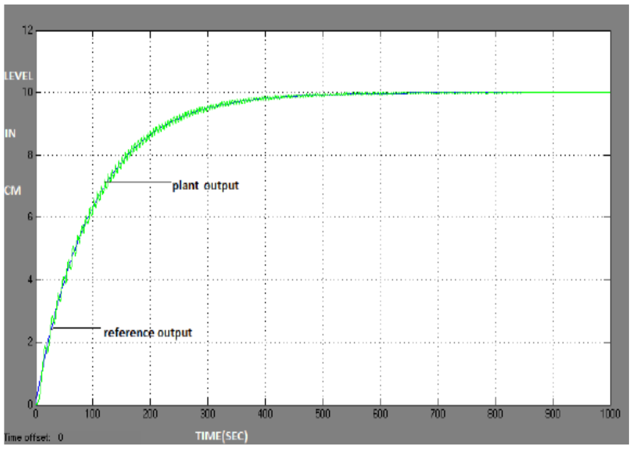

Fig.5 Response Of MRAC Feed Forward Gain.

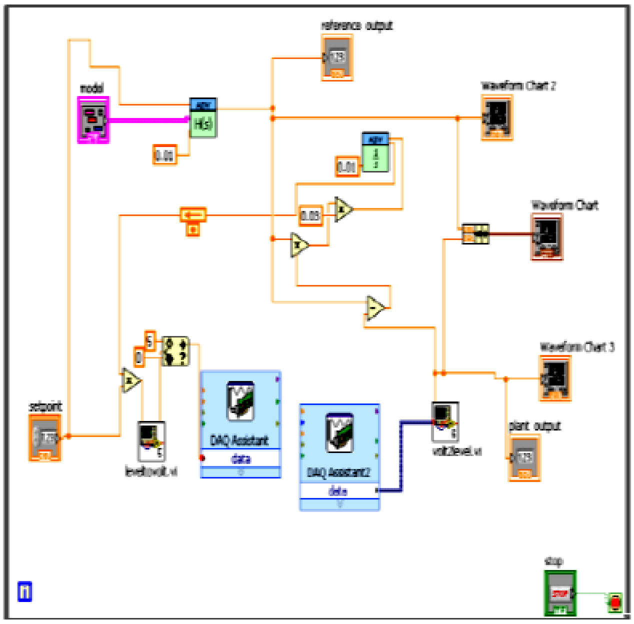

Fig.6 Block Diagram of MRAC Controller In Real Time Implementation.

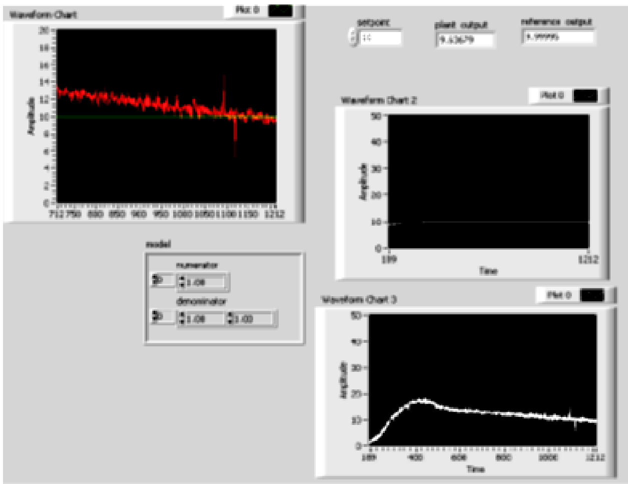

Fig.7 Response Of MRAC Controller In Real Time Implementation For Set Point 10

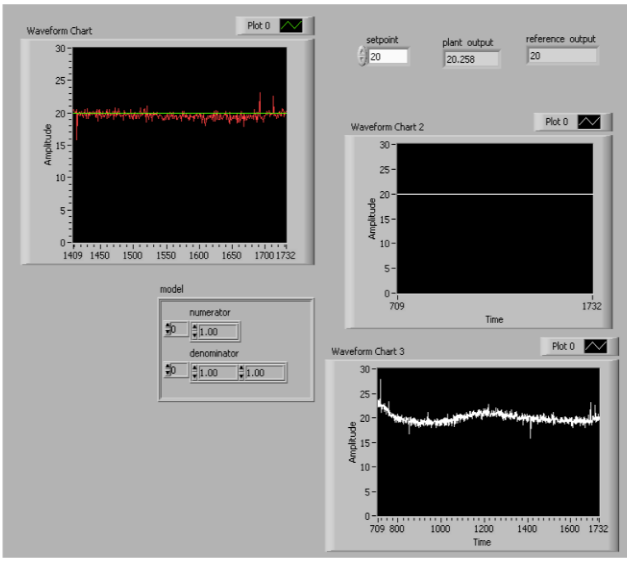

Fig.8 Response of MRAC Controller in Real Time Implementation for Set Point 20

Conclusion

The modeling of Spherical tank is done and the transfer function parameters are obtained from the modeling. The nonlinearity of the spherical tank is analysed. The Model Reference Adaptive controller is designed based on MIT rule for adjusting the feed forward gain. MRAC controller for first order system was implemented in LABVIEW environment for the real time control of spherical tank. In future the performance of MRAC can be compared with conventional controllers to prove its effectiveness in nonlinear system control.

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