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Design of Adaptive Controller for a Level Process

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Abstract— This paper presents the application of adaptive controller for a non-linear process and analysing the effect of the controller for the system. The controller chosen is a direct model reference adaptive controller (DMRAC) for adjusting the feed forward gain using MIT rule. The non-linear system considered is cylindrical tank. The model reference adaptive controller is designed and implemented in real time by using LabVIEW. The result shows that model reference adaptive controller shows better results than conventional Proportional Integral (PI) controller.

Keywords: MIT Rule, Cylindrical Tank, LABVIEW..

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I. Introduction

Various industrial processes are non-linear in nature and designing the controller for such type of process is very tedious. Non-linear process can be controlled by conventional controllers with certain modifications. Adaptive control has been developed to fulfil the demanding industrial applications since it can adapt to process variations. One of the popular and growing adaptive control method used in practical applications is model reference adaptive control (MRAC).

Many papers addressed the control of liquid level system. The accurate mathematical model-based strategies have been applied to deal with control problems. Due to the inherent nonlinearities and uncertainties present in the system, controlling the water level becomes a complex task. Anandanatarajan, Chidambaram and Jayasingh have brought out the limitations of the conventional PI controller tuned using Ziegler- Nichols settings [1]. Marian Tarnık and Jan Murgas applied the direct Model Reference Adaptive Control to Permanent Magnet Synchronous Motor (PMSM) to adapt the changes in the system parameters [2].

In this paper a procedure to design and implement MRACs for various non-linear systems is proposed. In MRAC, the error between the reference model output and the real plant output is used to adjust its parameters in order to control the plant. It has been demonstrated to be effective in controlling linear plants, and hence has found numerous applications in process control. In general, it performs better than conventional fixed parameter PID controller. It can better adapt to changes in the parameters of the plant, and therefore, has attracted numerous attentions in control engineering.

The linear MRAC performs well when it is working around the operating point, where the plant can be approximated by a linear model. The most industrial processes are highly nonlinear with various types of uncertainties and load disturbances, so the performance of the linear controller may deteriorate. Here the effect of MRAC for the non-linear system for level controls.

II. EXPERIMENTAL SETUP

The laboratory set up for this system consists of a cylindrical tank, conical tank and spherical tank. Figure 1 shows the real time experimental setup of process.

Figure. 1: Experimental setup

The level transmitter output is interfaced with computer using DAQ. This module supports 8 analog input and 2 analog output channels with the voltage range of +5 VDC. The pneumatic control valve is air to open, adjusts the flow of the water pumped to the tanks from the water reservoir. The level in the tank is measured by means of capacitive sensor and is transmitted in the form of (4-20) mA to the interfacing

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DAQ module to the Personal Computer (PC). The control signal from the PC is transmitted to the I/P converte in the form of current signal (4-20) mA, which passes the air signal to the pneumatic control valve. The pneumatic control valve is actuated by this signal to produce the required flow of water in the tank.

III. SYSTEM IDENTIFICATION

A. Mathematical Modelling

The dynamics of the tank system can be described by the first order differential equation.

$$\frac{d(V)}{dt} = q_1 - q_2$$

Where V is the Volume of the tank, q_1 is the Inlet flow rate and q_2 is the outlet flow rate and A is the area of the tank.

Where, $V = \pi r^2 h$

Smith have obtained the parameters of FOPTD transfer function model by letting the response of the actual system and that of the model to meet at two points which describe the two parameters τ and θ. Here the time required for the process output to make 28.3% and 63.2% respectively [5]. The time constant and time delay are calculated as follows.

At a fixed inlet flow rate, outlet flow rate, the system is allowed to reach the steady state. After that a step increment in the input flow rate is given, and various readings are noted till the process becomes stable for the three tank systems. The transfer function parameters are obtained from the experimental data for the operating region (0-20cm) is given below.

For the cylindrical tank,

$$G(s) = \frac{0.072}{60s + 1} e^{-5s}$$

After applying linearization, the transfer function can be written as,

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

where,

For the cylindrical tank,

$$\tau = R_t A$$

where R is the top radius and H is total height.

B. Empirical Modelling

The transfer function models are required only for the simulation studies of the controller design and it is not required in the real time design of model reference adaptive controller. Identification refers to the process of selecting a model structure first, and then estimating its parameters [4].The general First Order plus Time Delay Process (FOPTD) is selected as model structure and given by:

$$\frac{H(s)}{Q(s)} = \frac{k_p}{\tau s + 1} e^{-Ls}$$

IV. DESIGN OF DIRECT MODEL REFERENCE ADAPTIVE CONTROLLER

This section discusses the design of the conventional Model Reference Adaptive Control (MRAC). The basic structure of the MRAC is shown in Figure 2.

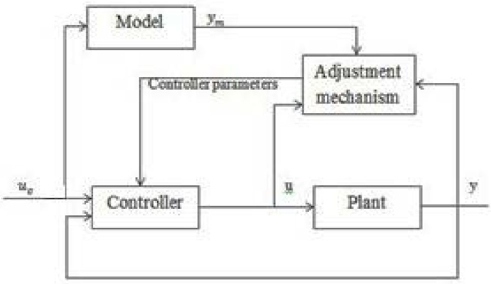

Figure. 2: MRAC

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 block diagram shows the structure of a model reference adaptive control (MRAC) system that is composed of process, controller, reference model and adjustment mechanism block. The block diagram 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 y_m, y, u and u_c [7]. The adjustment mechanism automatically adjusts controller parameters so that the behaviour of the closed loop control plant output (y) closely follows the reference model output (y_m). The system consists of two loops. The inner loop, which is an ordinary feedback loop consisting of the process and the controller. The outer loop, which adjust the controller parameters in such a way that the error,

$e = y - y_m$

A. Selection of Reference Model

The reference model represents a part of the design in the MRAC strategy. The performance specifications of the controller are given in terms of a reference model [5]. It sets the required performance of the closed loop system because it specifies the rise time, settling time, overshoot and other characteristics. The reference model must be chosen carefully so that the required performance can be achievable by the closed loop system. The reference model should have the same degree as the corresponding plant polynomial. It

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should be asymptotically stable as well as bounded-input or bounded- output stable. The reference model can be selected as a fast, medium or a slow type according to the nature of the process [8]. The reference model selected for the process is taken as,

$$G_m(s)= 1/(s+1)$$

which is a stable system and its degree is one; which is same as the degree of the process considered. The selected reference model is a fast model with time constant of 1second.

B. MIT Rule

The MIT rule is a gradient scheme that aims to minimize the squared model cost function.

$$J(\theta)=1/2\ e^2$$

To make J small, it is reasonable to adjust the parameters in the direction of the negative gradient of J, that is,

$$d\theta\ /dt = -\gamma e \frac{\delta e}{\delta\theta}$$

Where θ is the controller parameter. The sensitivity derivative is $\frac{\delta e}{\delta\theta}$.

The parameter γ is known as the adaptation gain [5, 6].

V. RESULTS AND DISCUSSION

The direct model reference adaptive controller is implemented in LabVIEW and applied to the non-linear system. The MRAC is tested for different setpoints for the system. The MRAC is tuned for the adjustment gain is 0.6 for cylindrical tank for the setpoint 30cm.The output responses for the setpoint 30 cm are shown in Figures 3 for cylindrical tank.

A. Comparison of MRAC with PI controller

The performance of MRAC is compared with conventional PI controller in terms of steady state error, settling time, and integral absolute error (IAE).

The comparison of the performance of the MRAC with PI controller for the setpoint 30 cm for the process tank is shown in Table I. It is observed that the steady state error is comparatively high by using conventional PI controller.

Also the process is settling faster by using MRAC. The performance evaluation in terms of integral absolute error (IAE) shows that MRAC shows better results than the conventional PI controller.

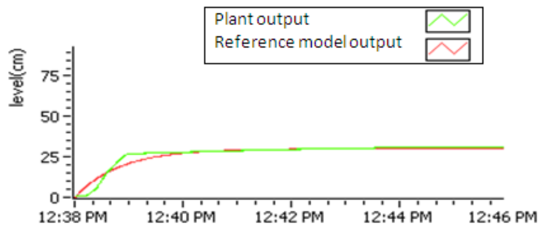

Figure 3: Real Time Response of Cylindrical Tank using MRAC (setpoint 25 cm).

VI. CONCLUSION

The mathematical modelling of the tank is done and the transfer function parameters are obtained from the empirical method. The model reference adaptive controller is designed based on MIT rule for adjusting the feed forward gain for the system. The comparison in Table I show that the model reference adaptive controller tuned for setpoint 30cm.

Table I: *Comparison of PI and MRAC.*

System	Controller	Plant output (cm)	Steady state error (cm)	Settling time(s)	IAE
Cylindrical Tank	PI	31.61	1.61	1.76	2645.9
	MRAC	30.99	0.99	108	1601.5

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