

Identification and Control of a Cylindrical Tank

Based on System Identification Models

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Abstract – Advancements in the process control industry has made difficulties in controlling processes which are highly complex in nature. System identification provides a better solution for this problem with the help of identification models. In this paper ARX, ARMAX, BJ and OE models were used for the identification of a cylindrical tank and Ziegler Nichols tuning method to develop the controller for controlling the level of the tank. The proposed method provides simple and accurate models and thereby improving the efficiency of identification process. MATLAB and LABView softwares were used here for identification and controlling.

Keywords – ARX, ARMAX, OE, BJ, Ziegler Nichols tuning method.

I. INTRODUCTION

Real world systems are highly complex and diverse in nature which made it difficult for controlling various process related with them. So the best method to deal with them is to obtain the best model for the systems related to it. Models of the system can be obtained through various methods like mathematical modeling, empirical modeling and so on. The problem arises when the model obtained through these methods does not show similarities to the system. So to obtain the best models of the systems we should go for system identification process. System identification is a methodology for building mathematical models of dynamic systems using measurements of the system's input and output signals. System Identification can also be done through the various methods like structure based identification, fuzzy based identification, neural network based identification, etc. All these methods make use of different approaches to get the model. The accuracy of the obtained model varies according to the process. ARX, ARMAX, OE, BJ and so on models will be used mainly when the system is linear in nature and when they are time variant.

Mathematical and empirical modelling technique requires prior details about the system for identification process. All those techniques make use of only limited amount of data for developing the model. So the developed model shows less similarities to the original system. In model based identification process we make use of the input and output data obtained from the step response alone for the identification process. The study also reveals that this approach of identification simplifies the tedious mathematical computation and provides with much simpler and accurate models and also helps in analysis of many features about the obtained model so that the model satisfies the desired requirements.

II. SYSTEM IDENTIFICATION

The methodology of building model from the measurement of systems input and output signals is called system identification. System identification finds application not only in control area but in fields like communication, pattern recognition, fault analysis, etc.

System identification involves the following three steps.

1. Data set: The input and output samples which were obtained from the system. It should be collected experimentally depending on the requirements.
2. Model structure selection: A model describes the relationship between the observed variables and the best model is to be computed from the model structure according to the input-output data and a given criterion of fit. The criterion reflects the objectives of the modeler. It expresses the effectiveness of the model in representing the observed data.
3. Model Validation: The process of estimating whether the obtained model is good or not.

III. SYSTEM IDENTIFICATION MODELS

1. ARX Model

This model describes a relation between the input, error and output and most of the single input single output relationship is represented by this linear equation, which is given by,

$$A(q)*y(t) = B(q)*u(t) + e(t) \quad (1)$$

where,

$$A(q) = 1 + a_1 q^{-1} + a_2 q^{-2} + \dots + a_{na} q^{-na}$$

$$B(q) = b_1 q^{-1} + b_2 q^{-2} + \dots + b_{nb} q^{-nb}$$

$u(t)$ is the command signal, $y(t)$ is the output, $e(t)$ is the white noise. The block diagram representation of ARX model is shown in Figure 1.

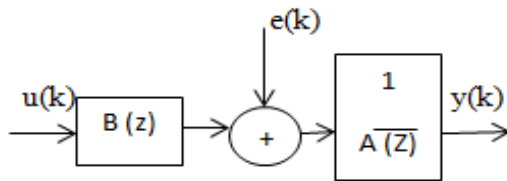


Fig. 1: ARX Model

The model is used to describe plants where much freedom is not required for the description of errors.

The parameter vector to be estimated in this model is,

$$\Theta = [a_1 a_2 a_3 \dots a_{na} b_1 b_2 b_3 \dots b_{nb}]^T \quad (2)$$

2. ARMAX Model

This model describes a relation between the input, error and output and most of the single input single output relationship is represented by this linear equation, which is given by,

$$A(q)*y(t) = B(q)*u(t) + e(t) \quad (3)$$

where,

$$A(q) = 1 + a_1 q^{-1} + a_2 q^{-2} + \dots + a_{na} q^{-na}$$

$$B(q) = b_1 q^{-1} + b_2 q^{-2} + \dots + b_{nb} q^{-nb}$$

$u(t)$ is the command signal, $y(t)$ is the output, $e(t)$ is the white noise. The ARMAX model has become a standard tool in control and econometrics for both system description and control design. ARMAX model is the most efficient and commonly used model for linear system identification. The block diagram representation of ARMAX model is shown in Figure 2.

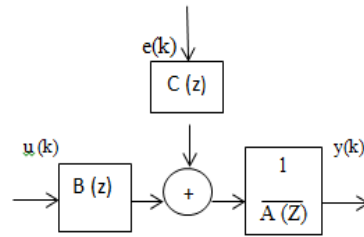


Fig. 2 : ARMAX Model

3. OE Model

The Output-Error (OE) model structure describes the system dynamics separately as shown in Figure 3.

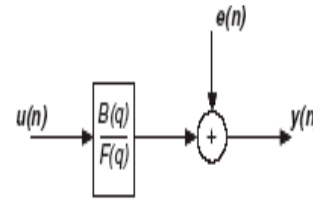


Fig. 3: OE Model

For modelling the disturbance characteristics no parameters are used.

4. BJ Model

The Box-Jenkins (BJ) structure provides a complete model with disturbance properties modelled separately from system dynamics. The block diagram is given in Figure 4.

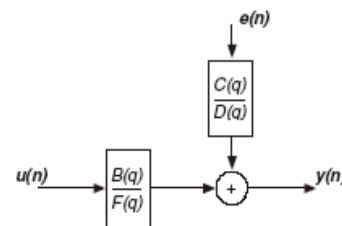


Fig. 4: BJ Model

This model is useful when disturbances enter late in the process. For example, measurement noise on the output is a disturbance late in the process

IV. ZIEGLER NICHOLS TUNING METHOD

Several techniques had been used for the tuning of PID controllers that are used in the process. Ziegler Nichols tuning is one among them to find out the PID parameters which was developed by Ziegler and Nichols in 1942.

In this tuning method the plant will be applied with an step response. The response will be characterised by two parameters L and T. The parameters can be

obtained by drawing a tangent to the step response at its point of inflection and noting its intersections with the time axis and the steady state value.

The process model can then be described as

$$G(s) = \frac{Ke^{-sL}}{Ts+1} \quad (4)$$

The controller parameters based on the method is described in the Table 1.

Table 1: PID parameters

PID Type	K_p	$T_i=K_p/K_i$	$T_d=K_p/K_d$
P	$\frac{T}{L}$	∞	0
PI	$0.9\frac{T}{L}$	$\frac{L}{0.3}$	0
PID	$1.2\frac{T}{L}$	$2L$	$0.5L$

The controller parameters for all the three ie; P,PI and PID controllers are given in the table.

V. PROCESS DESCRIPTION

Level process station is selected for the identification process. Cylindrical shaped tank was used in it. Our aim was to control the level of the tank through proper identification of the process through system identification models like ARX, ARMAX and OE. Controlling can be done with the help of Ziegler Nichols tuning method.

The laboratory set up consists of a cylindrical tank, a water reservoir, pump, rotameter, level transmitter, an electro pneumatic converter(I/P), a voltage to current converter (V/I), a current to voltage converter(I/V), a pneumatic control valve, DAQ connector and a Personal Computer. The sine wave given as the input to the pneumatic control valve determines the opening rate of valve and thus adjusts the flow of the water pumped to the spherical tank and cylindrical tank from the water reservoir. The sine wave generated between 0 to 5v is converted to the corresponding current value between 4-20mA and then by using I/P converter air signal is generated and passed to control valve. The level in the tank is measured by using a level transmitter in the form of 4-20 mA and is converted to voltage of 0-5v using current to voltage converter and send to the Personal Computer. The block diagram representation of the entire process will be as shown in the below Figure 6.

The input and output samples required for the identification process was obtained with the help of LABView software. Identification of the tank was done in MATLAB using MATLAB system identification toolbox and controlling was done with the help of LABview software. For the identification process 1000

input output samples were taken with a sampling rate of 1second.

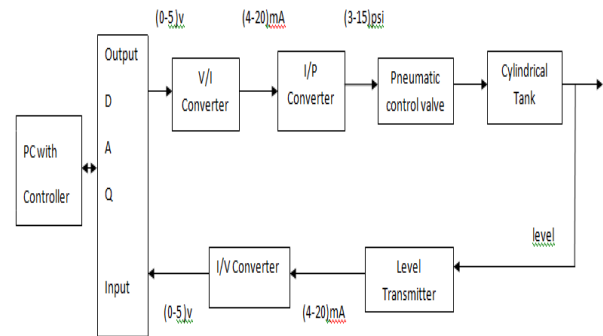


Fig. 6: Block diagram of the process

VI. RESULT

The response of the system to various types of models were analysed. Mainly three types of models were used for these purpose. ARX, ARMAX and OE models. After checking the percentage of fitness of the obtained models, controller was designed and the closed loop response of the system was analysed.

The various model outputs comparison is shown in Figure 7 with amplitude in X-axis and time in Y-axis

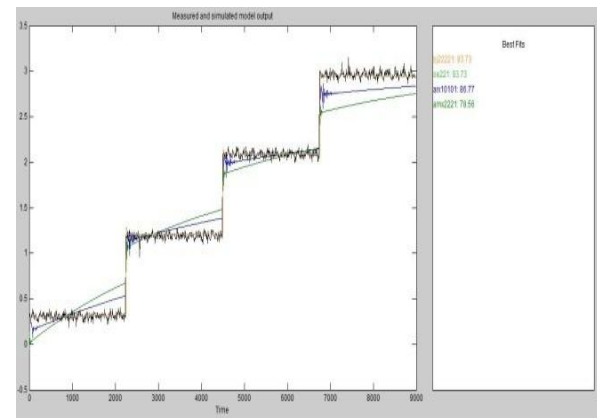


Fig. 7: Model outputs

Its clear from the graph that BJ and OE model shows the best results.

Then the controller was designed and introduced into the process. The process transfer function from the systems step response can be given as:

$$G = 2.66/(70s+1) \quad (5)$$

where the effect of delay can be neglected, since its very low. The controller parameters obtained are:

$$K_p = 2, \Gamma = 0.2.$$

Hence the controller transfer function can be given as:

$$G_p=2(1+0.2s)/0.2s \quad (6)$$

The system output after the introduction of the controller is shown in Figure 8 for various models with time on X-axis and gain on Y-axis..

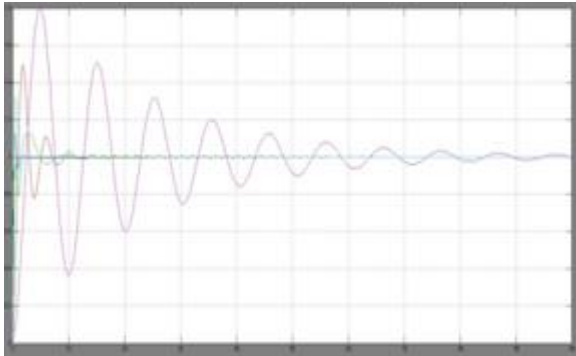


Fig. 8: Output response with controller

From the figure we can identify that if we are using the model based identification method the system can be controlled effectively than that obtained from the empirical modeling. Comparison between the various output responses are shown in Table 2

Table 2: Comparison of output responses

Models	Settling time (seconds)	Peak Overshoot (%)
ARX	62	30
ARMAX	115	50
OE	35	20
BJ	85	10
Mathematical Model	200	80

The responses were analysed over here based on the time domain and frequency domain characteristics.

VII. CONCLUSION

System identification can be done in many ways. But the identified parameters vary depending upon the method used. From the above results its clear that model based system identification provides better results than the other conventionally used methods. System Identification models also differ in their response depending on the selection of the orders. Among the ARX,ARMAX,BJ and OE models used over here,OE model shows the best closed loop response. It has less settling time and peak overshoot.Here we are using only offline identification method which will give only one set of system parameters. In future we can go for online

identification which provide the proper controlling throughout the process.

VII. REFERENCES

- [1] Alireza,Rahrooh and Scott Shepard,“Identification of nonlinear systems using NARMAX model.” Nonlinear Analysis 71 (2009) 1198-1202.
- [2] Boyi Ni and Deyun Xiao,(2006) ,”System Identification and simulation Toolbox under MATLAB Environment”,Journal of System Simulation.18(6):88-900.
- [3] Brian R Copeland “The Design of PID Controllers using Ziegler Nichols Tuning” ,March 2008.
- [4] Brian R Copeland Ljung.L(1999),System Identification Theory for the User, 2nd ed.Prentice Hall
- [5] MATLAB system identification toolkit user manual.
- [6] Nithya,S,Sivakumaran.N,Balasubramanian.T and Anantharaman.N,”IMC based Controller design for a Spherical Tank Process In Real Time”,National Conference in Advanced Techniques in Instrumentation Control and Communication Engineering,pp.173-178. (2008)
- [7] Nora Taghavi, and Ali Sadr, “Piezoelectric Transducer Modeling: with System Identification (SI) Method.” World Academy of Science, Engineering and Technology 39, 2008.
- [8] Sudeep Sharma, Vijay Kumar, Raj Kumar, “Supervised Online Adaptive Control of Inverted Pendulum System Using ADALINE Artificial Neural Network with Varying System Parameters and External Disturbance”,I.J. Intelligent Systems and Applications, 2012.

