Modeling and System Identification of Liquid Level System

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***Abstract*— The first stage in the development of any control and monitoring system is the identification and modeling of the system. Therefore, system identification has been a valuable tool in identifying the model of the system based on the input and output data for the design of the controller. The present work is concerned with the identification of transfer function models using open loop test for Liquid Level system.**

Keywords— System Identification, Liquid Level System. Mathematical modeling, Process reaction curve, Open-loop response.

I. INTRODUCTION

The process of constructing models from experimental data is called system identification. System identification involves building a mathematical model of a dynamic real time system based on set of measured input and output data (raw data). It is a process of acquiring, formatting, processing and identifying mathematical models based on raw data from the real-world system. It is beneficial to first develop a model of the system to control a system precisely. The main objective for the modeling task is to obtain a good and reliable tool for analysis and control system development.

In the present work, the system identification of real time liquid level system is done using real time data. The paper is organized as follows. In Section-II, the process description is discussed. In section-III, mathematical modeling of system is covered. In section-IV, the process identification of system is discussed. Section-V gives model validation and section- VI is about conclusion.

II. DESCRIPTION OF THE LIQUID LEVEL SYSTEM

In the present work, the real time Level control trainer is used as dedicated system available in process control laboratory for collecting the input-output data. Level Control Trainer (product code 313,313A) supplied by Apex Innovation is used here [1]. The process setup consists of supply water tank fitted with pump for water circulation. The level transmitter used for level. The process parameter (level) is controlled by microprocessor based digital indicating controller (we will not going to use that controller, it is bypassed) which manipulates pneumatic control valve through I/P converter. A pneumatic control valve is used to adjust the water flow in to the tank. These units along with necessary piping are fitted on support housing designed for table mounting. The P&I diagram is as shown in fig.1

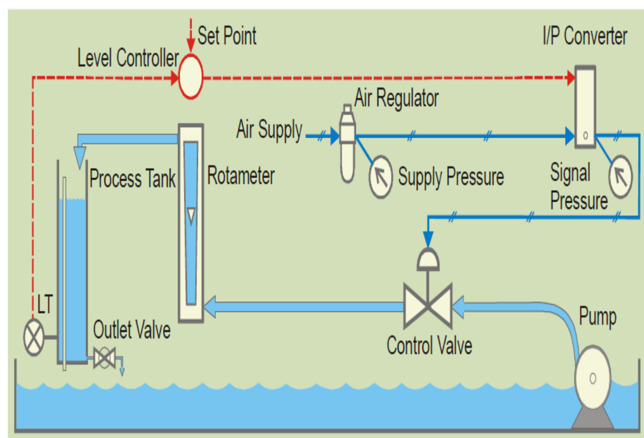

Figure 1. P&I diagram of Liquid Level System

The real time level system is as shown in fig.2 and the specifications are tabulated in Table 1.

Components	Details
Rotameter	10-100 LPH
Process tank	Transparent, Acrylic, with 0-100% graduated scale
Supply tank	SS304
Level transmitter	Type- Electronic, two wire transmitter, Range 0–300 mm, Output 4–20mA
I/P converter	Input 4-20mA DC, Output 3-15 psig

Table 1. Instrument Specifications.

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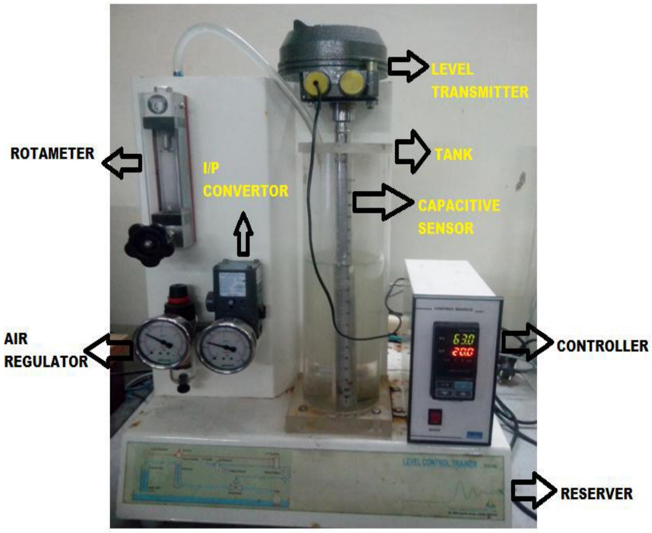

Figure 2. Liquid Level Trainer

III. MATHEMATICAL MODELING

The system can be modeled by different methods like First Principle method and Empirical Method. In First Principle method, dimensions and instrument specification are used to formulate the transfer function of system whereas in case of Empirical method experimental input-output data is used to find out the process model. Here, first we find the mathematical model of the system by First Principle method [2].

FIRST PRINCIPLE METHOD

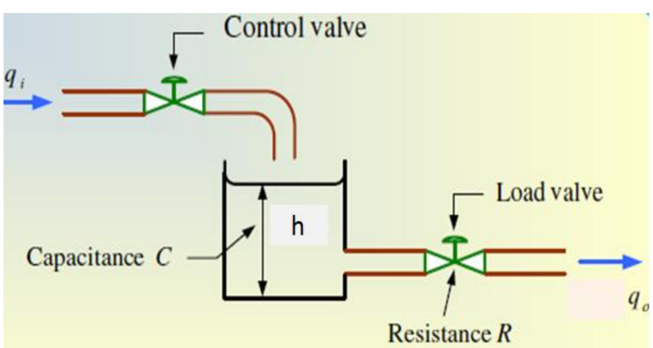

Figure 3. Schematic diagram for the Liquid Level System

$$\textit{Rate of change of fluid volume in the tank} = \textit{flow in} - \textit{flow out}$$

$$\frac{dV}{dt} = q_i - q_o \ldots\ldots\ldots\ldots (1)$$

Where, q_i is flow in, q_o is flow out, V is volume.

$$\frac{d(A\times h)}{dt} = q_i - q_o \ldots\ldots (2)$$

$$A\frac{dh}{dt} = q_i - q_o \ldots\ldots\ldots\ldots (3)$$

Where, A is area of the tank.
The resistance R may be written as

$$R = \frac{h}{q_0} \text{ Or } q_0 = \frac{h}{R} \ldots\ldots(4)$$

After simplifying above equation (3) and (4), we get

$$RA\frac{dh}{dt} + h = Rq_i \ldots\ldots (5)$$

$$RAsH(s) + H(s) = RQ_i(s) \ldots(6)$$

$$\text{TF=} \frac{H(s)}{Q_i(s)} = \frac{R}{(RAs+1)} \ldots\ldots\ldots (7)$$

RA Indicate time constant of the system.

For our dedicated system, q_i is consider constant at 50% valve open, q_o is set at 0.8 cm^3/sec. Area of tank is 60.445 cm^2. As per the equation (7) the mathematical model of the level system is given as:

$$G(s) = \frac{1}{60.445s + 0.052} \ldots\ldots (8)$$

IV. PROCESS IDENTIFICATION

The determination of the dynamic behavior of a process by experiment is called process identification. The second method for the system identification is Empirical method in which the experimental input- output data is used. In this section, the transfer function model using process reaction curve method is discussed for which the input and output data are generated from the real time system.

Many industrial processes are of high order systems. To design a controller equations for such processes are not easily available. Hence, it is desirable to model these processes by low order models such as FOPDT or SOPDT models [3]. Here, the time domain curve fitting of step response is studied to identify an FOPDT or SOPDTZ model of a process. This method requires the response of process, initial estimates of model parameters and assumption of a suitable model. The initial selection of the model could be based on the shape of the open-loop step response. Open-loop identification is widely used in the industry. In open loop step testing, a step change in input is applied to the process which will produce a corresponding response. It is called process reaction curve. In the chemical industry, for many processes the process reaction curve is an S-shaped curve. To obtain an open-loop step response (Y_a), the process should be perturbed by introducing a step

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change in the manipulated variable (MV), as shown in Figure 4.

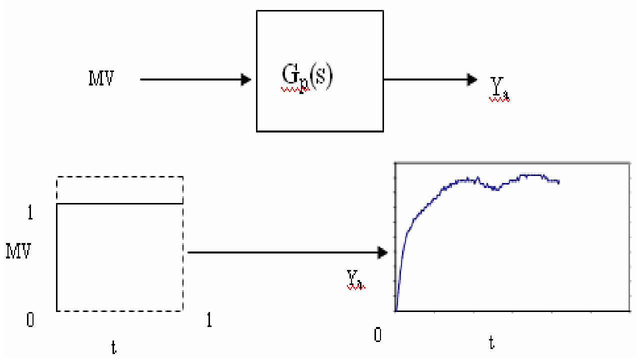


Figure 4. Block diagram and input/output graph of open-loop test.

Here, input and output data is collected using LabVIEW interfacing and stored that data into Express files. These data is imported to System Identification Toolbox in MATLAB. The transfer function of the process is obtained in form of process model as FOPDT form

$$G(s) = \frac{1.0451}{270.07s + 1} e^{-28.863} \quad ..... (9)$$

The open loop step response of real time system is shown in fig.5.

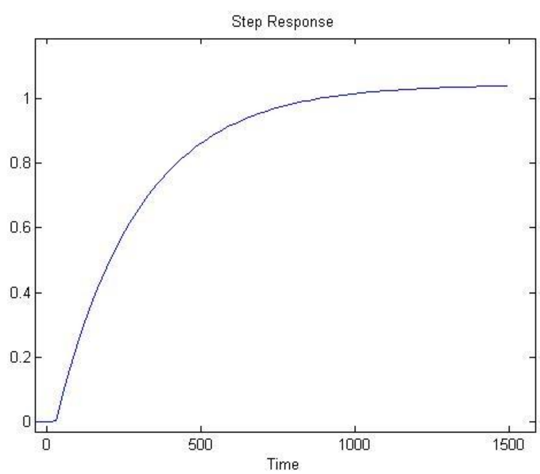


Figure 5. Step response of level system

V. MODEL VALIDATION

This section contains how the identified model is to be validated. For validation, Comparing simulated or predicted model output to measured output. This comparison gives 95.71% fit; the estimated model is more probably matched the actual process as shown in figure 6.

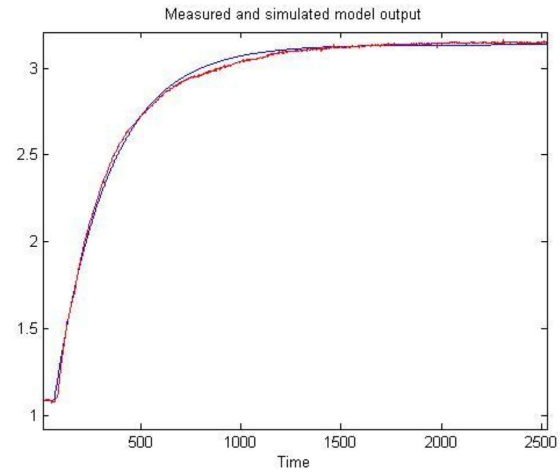


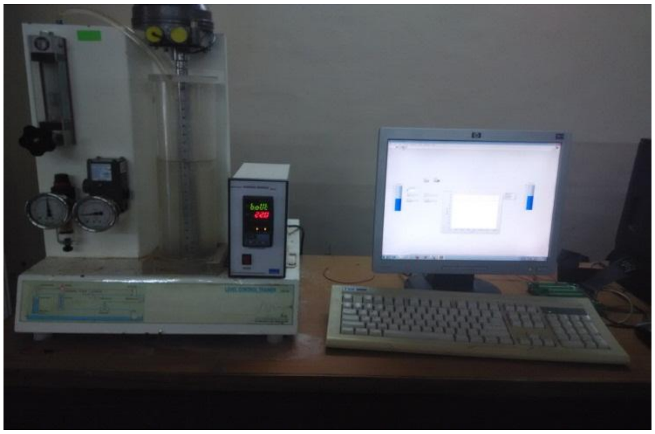
Figure 6. Comparison of Simulated and Measured output.

VI. CONCLUSION

In this paper, the system identification of the liquid level system is done and the mathematical model of the system is obtained. A plant model is very useful for analysis of the system, design of controller, fault identification and etc. In most of the method, open loop identification approach is used. For different industry, it is useful for development of plant model. Open-loop identification by time-domain curve fitting of step response was studied using both simulated and experimental data. Process identification using simulated data revealed that there was only a slight disparity in model parameters under open-loop.

APPENDIX

The raw data used for the system identification in the paper can be collected from real time system using LabVIEW and compatible DAQ card. The liquid level system is interfaced with LabVIEW professional trough DAQ. The real time system is interfaced with LabVIEW professional is as per the shown in figure below.



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