Scientific Journal of Impact Factor(SJIF): 3.134
e-ISSN(O): 2348-4470
p-ISSN(P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 2, Issue 5, May -2015

Flow Control Loop Analysis for System Modeling & Identification

J.S Rajashekar[1], Dr. S.C. Prasanna Kumar[2]

[1]Faculty of Instrumentation Technology, Dayananda Sagar College of Engineering, Bangalore and Research scholar of Jain University, Bangalore, Karnataka, India.
[2]Professor & Head, Department of Instrumentation Technology, R.V. College Engineering, Bangalore, Karnataka, India.

Abstract: *Process control equipments are designed to operate the plants on a steady state basis and are most important to determine the performance of automatic control system. Control of the process requires thorough control knowledge, the behavior of the process components, process details, and inter-relation within the sections of the process plant. The effects of control components on process identification are backbones of effective and efficient process control. These components are more susceptible to failure due to many reasons such as degradation of components, high operating value, backlash, friction etc. The deterioration of these component may due to wear and tear, hostile atmospheric conditions, drift due to temperature changes, hysteresis etc. Some faults or abnormality results in non-uniformity in process output and further may lead to plant shutdown. Modeling of these components provides accurate description of component dynamics that is helpful for condition monitoring and further for failure analysis.*

This paper is concerned with the study & analysis of flow control loop components, where by experimentation carried out on an industrial type control valve, I/P converter, orifice in the laboratory. Effective data collection of these components, consisting of literature gathering and some tests such as step and vibration on these components, is performed using which modeling equations are formed in MATLAB. The raw data can be used to describe system response and formulate the suitable algorithm using programmable Hybrid controller. Empirical data based modeling and analyses are the key features of this paper.

Key words*: Process identification, experimental data, modeling, process control, transfer function, hybrid controller*

I. INTRODUCTION

Many industrial processes inevitably change over time for a variety of reasons that include: equipment changes, different operating conditions, or changing economic conditions. The processes are controlled today, based on proven techniques like PID controller, fuzzy based controller etc. Consequently, a fundamental control problem is provides effective control of complex processes where significant process changes can occur, but cannot be measured or anticipated. The conventional solution is controller tuning for worst case condition. However, this approach can result in poor control system performance for more typical conditions. In the past, it has been observed and experienced that the process identification in closed loop was difficult. The effect of control components on process identification are the backbones of effective and efficient process control. There are many experiments carried out to develop appropriate model using various techniques. The classical theory of control system utilizes the method of identifying the process, modeling the process, approximating the system of adequate order, and suggesting a matching control system, usually a feedback control system. For better control, the techniques include modeling based on first principle, empirical modeling, and nonlinear process control. The challenge is correctly modeling the process and implementing the control.

A typical control loop comprises of sensor, actuator, process, and feedback module. The effect and interaction with individual element in the same loop is to be understood before one can really go for controlling. This paper focuses on the analysis and study of the effect of control components on process identification through experimentation carried out in the department process control laboratory. The process identification and modeling on control components like sensor, I/P converter, and final control element for a flow loop module. Honeywell HC900-C30 is used for acquiring data and sending it to computer for further processing and analysis. Control designer software is used to build a traditional PID controller to analyze the control performance without taking into account control components. The analysis will help in identifying the effect, and process identification will become more realistic.

II. PROCESS IDENTIFICATION OBJECTIVES

The important aspect of process identification is finding mathematical model or transfer function of the system. Modeling is required to understand the dynamics of process and to obtain mathematical description. Mathematical model of any physical system is characterized by differential equation and the differential equation can be reshaped in to different form for analysis and one such form is transfer function.

The basic assumption in process control practice is that the process to be identified is approximately linear. However process identification requires extensive measurement, because it relies entirely on experimentation. Many techniques have been developed for process identification and control. The degradation of the loop components is another area of concern for process identification and control. The first step towards accurate process identification is to have an accurate sensor model where the measurement is difficult. A mathematical relationship that determines the unmeasured variable based on prediction and knowledge from the physical insight was established. Control valve, more commonly called, as final control element is the most important control component. Major problems in control valve are stiction, hysteresis, and wear and tear of trim. These components largely influence the process identification and control.

MATLAB® is a high performance language for technical computing. It integrates computation, visualization and programming in an easy-to–use environment where problems and solutions are expressed in familiar mathematical notation. System Identification Toolbox extends the computation environment and fit linear and nonlinear mathematical models to input and output data from dynamic systems. System identification is especially useful for modeling systems that we cannot easily represent in terms of first principles. Real-time applications System Identification Toolbox support both time- and frequency-domain data with single or multiple inputs and single or multiple outputs. We can also use this Toolbox to estimate models for time-series data. Adaptive control, adaptive filtering, or adaptive prediction can use System Identification Toolbox to perform recursive parameter estimation. The typical identification workflow includes : i) Prepare data for system identification by: Importing data into MATLAB workspace; Plotting data on a time plot or an estimated frequency response plot to examine the data features and preprocessing the data by removing offsets. ii) Define a model structure, estimate and validate models. iii) Assess the effect/ performance degradation of control components iv) Use simulation or prediction of future output using the model.

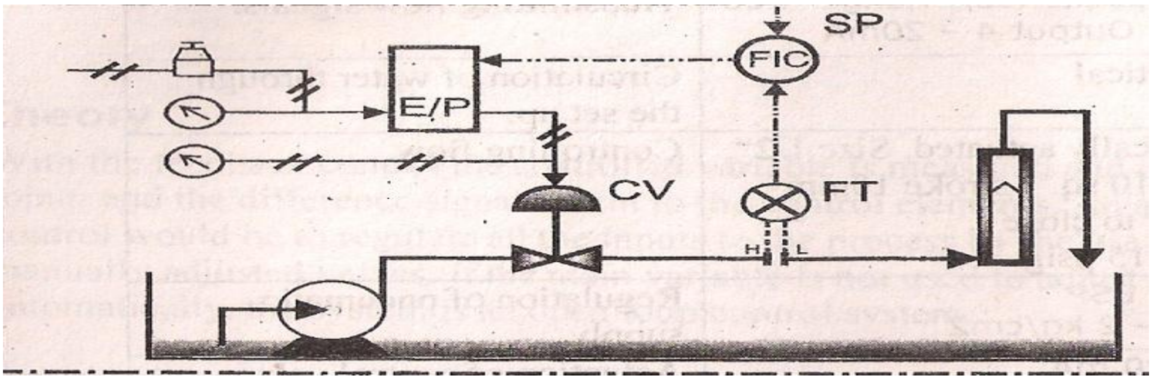
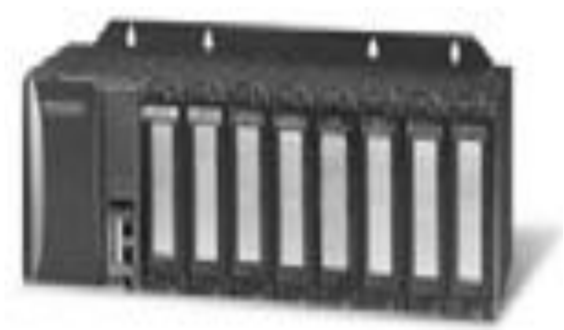


Figure 1. Flow process loop

The focus of the study was on assessment of the effect of control components on process identification. The flow loop consists of various components such as tank, Pipe, Pump, Orifice plate, Venturi tube, Transmitter, I/P converter, Control valve, rotameter and manually operated valves. The flow loop involved is a closed loop process as shown in above figure.1. The loop components such as control valve, I/P converter and orifice are modeled and studied. The response time, settling time, and hysteresis of the components were considered as basic requirements of the sensor performance characterization. Various schemes for data generation are implemented, like step; ramp and soak. And we use the existing control technique of process like the PID controller. Looking at this requirement, detailed experimentation was carried out based on various parameters. The performance degradation of the control components is a major reason for necessity of retuning of controllers. An estimation of performance degradation, through characterization of the components is being implemented, through experimentation. A method was developed using HC900-C30 Hybrid controller (Figure.2) module to assess the dynamics of the process plant within the operating limit. Finally an appropriate control strategy was developed and implemented to control the pilot plant using control builder (Figure 3).



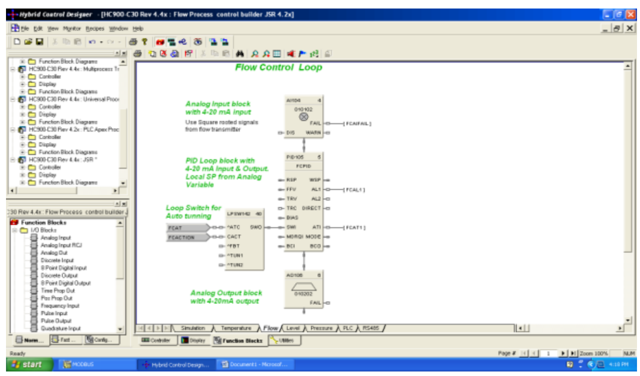


Figure 2. Hybrid controller: *Courtesy Honeywell* Figure 3. Control builder

III . EXPERIMENTAL RESULT & OBSERVATIONS

Using those aspects of transfer function and process model, experimentation is carried out on the flow loop components actually tested and the result or observations are used in building a model. Generally least square techniques are used to estimate parameters in discrete time autoregressive model. The model parameters are then verified by applying the model to a different subset of the data. If the model predictions match the measured outputs reasonably well, then the discrete model is usually acceptable for discrete control system design and analysis. The stability of a discrete transfer function is determined from the values of the poles of the denominator polynomial. The result obtained are encouraging and revealing the fact that process identification and control can be handled using matlab tools & hybrid controller.

Test Result

1. Best Fit – Control Valve

The characteristics of control valve for stem travel against current input shown in fig 4; by using these observations and readings, model is found out. The data are imported in Matlab workspace with the help of system identification toolbox to estimate process transfer function.

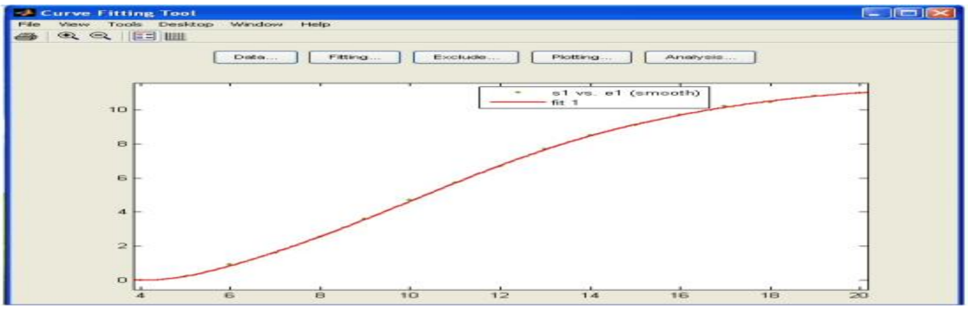


Figure 4. Control valve characteristics.

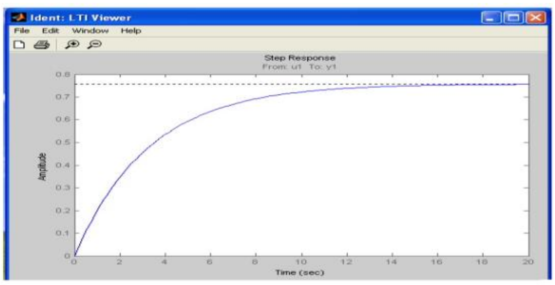
Control Valve Transfer Function

$$G(s) = \frac{K}{1 + sT_{p1}} e^{(-sT_d)}$$

with K = 1.4605 Tp1 = 2.5008 Td = 0

Step Test for Control Valve;

For step test initially the valve is kept at its normal position. Full step of 0% to 100% (4 ma to 20 ma) is applied to control valve. Required time interval observations are noted. Time required for 100% opening, settling time and time constant is noted. Further the graph is plotted for time in seconds versus stem travel in mm. by applying procedure the waveform obtained from Matlab is as shown in figure 5.



Sr. no.	Percentage of rise	Time (sec) by experimentation	Time (sec) by MATLAB
1	0 to 63.2 %	3.5	3.0
2	0 to 90 %	8.0	7.2

Figure 5. Step response of control valve

2. Best Fit – I/P converter

Figure. 6 shows the characteristics of current to pressure converter. I/P converter give linear characteristics for pressure output with current as input. It converts electronic 4-20 ma input to 3-15 air pressure psig control signal. I/P converter are a first order instrument and hence the transfer function is somewhat simpler.

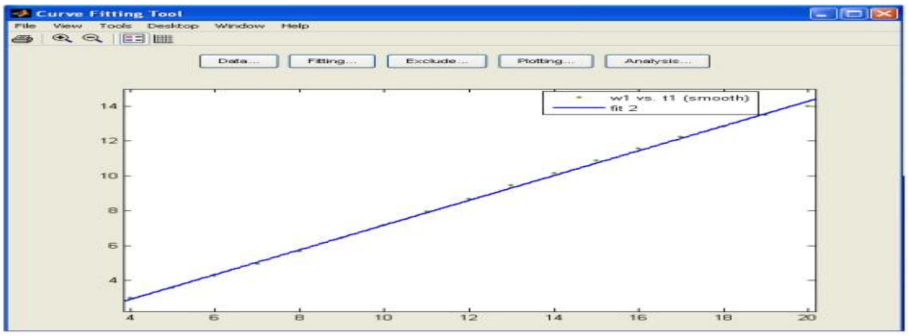


Figure 6. I/P converter characteristics

From the observations and graphs, a model and transfer function is found out with the help of Matlab software.
Transfer Function of I/P Converter

$$G(s) = \frac{K}{1 + sT_{p1}} e^{(-sT_d)}$$

With K = -11.368 Tp1 = 71.49 Td = 20.063

Step Test for I/P converter

Full step of 0% to 100% (4 mA to 20 mA) is applied to I/P converter. The output of I/P, which is pressure 3-15 psi signal. The results are compared which includes time constant and settling time as shown in figure 7.

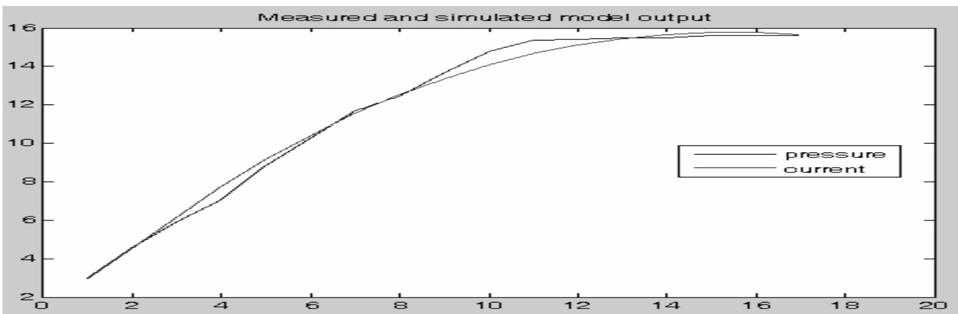


Figure 7. Step response I/P converter

.

3. Best Fit – Orifice plate

Figure 8 shows the characteristics of orifice plate for flow against differential pressure. From the observations and readings the transfer function of orifice with process model is found out using Mat Lab.

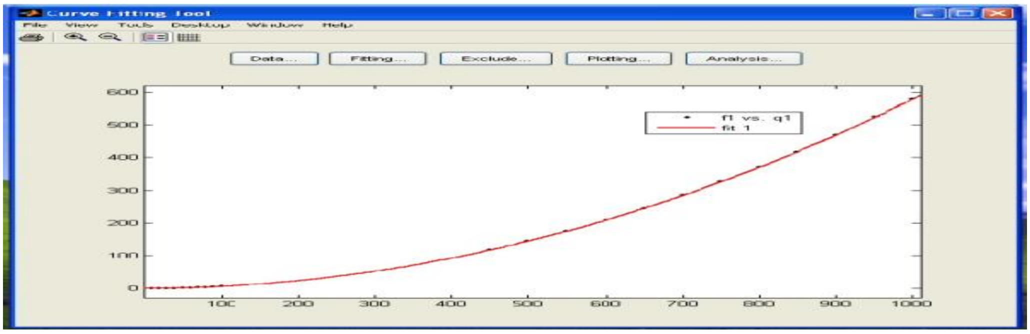


Figure 8. Orifice plate characteristics

Orifice plate transfer function

$$T.F. = \frac{3.0006}{1897.1s + 1}$$

Sr. no.	Percentage of rise	Time (ms) by experimentation	Time (ms)by MATLAB
1	0 to 63.2 %	65	58
2	0 to 90 %	142	136

IV. CONCLUSION

Using process identification technique we can obtain transfer function of any system. In conclusion it can be stated that, all the systematic approach for data generation, validation, processing and identification of for various processes will be beneficial. With some modification we can use our module with real time applications. Through the experimentation it has observed that the quality of data decides the success data driven modeling structure. Model presented here is the property and characteristics of component itself. Process loop components with some tests such as step, vibration & noise analysis can be performed and modeling equations can be developed.

REFERENCES

[1] L. Ljung, System *Identification Theory for the User*, 2nd ed. Englewood Cliffs, NJ: Prentice-Hall.
[2] I. D. Landau, “Identification in closed loop: A powerful design tool” *Control Engineering Practice*. vol.9, pp. 51–65,
Jan. 2001
[3] HC 900 Hybrid Controller Operation & Configuration reference Manual
[4] Dale E. Seborg, Thomas, Duncan, Process Dynamics & Control, J.Wiely& Sons
[5] Mohamed Sharif, Roger I. Grovenor, “Fault Diagnosis in Industrial Control Valves and Actuators” in *IEEE Instrumentation and Measurement Technology Conference, May 1998, pp 770-778.*
[6] Bequettte.B.W, *Process Modeling, Simulation, & Control for Chemical Engineers* PHI.
[7] Wei Xing Zheng “A Modified Method for Closed-Loop Identification of Transfer Function Models *in IEEE transactions on* CIRCUITS *AND SYSTEMS, VOL. 49, NO. 4, APRIL 2002, pp 556-562.*

