Identification and control of SISO systems using relay and subspace method

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ABSTRACT

In the present investigation, a new closed loop identification method for the single output and single output (SISO) systems & control of identified SISO systems has been proposed. For identification of SISO system, relay feedback & subspace identification methods have been employed simultaneously to determine the system transfer function matrix by state space model using N4SID algorithm from system identification toolbox. The proposed identification method requires neither priori knowledge to carry out identification unlike subspace identification method nor involves excessive calculations unlike auto tuning using relay-feedback method. Examples based on stable transfer functions are considered to observe the efficacy of the proposed method. The main advantage of this design method is its simplicity and reduction of excessive calculations, when compared to other methods in the literature. A new method has been proposed in order to identify and control the commonly used SISO processes such as FOPTD and SOPTD in process control applications. Different bench mark examples from the literature have been considered for the illustration of the proposed method. A comparison between the identified process and actual was done and found that the results are in good agreement.

Keywords: FOPTD, SOPTD, Relay-Feedback, Subspace Identification, System Identification, SISO, PID-Controller, N4SID.

1. INTRODUCTION

Identification and control plays an important role in the process control community. For any process to optimize, control one needs to identify the processes. Identification can be carried out by either by two ways one by using the mathematical modeling or experimental data, mathematical modeling involves the obtaining the process transfer function by using the first principles or empirical laws or mathematical modeling involves the rigorous calculations and involves the lot of assumptions. System identification plays an important role for the identifying the process. System identification was the tool used for the obtaining the input and output data from experimental data for the controlling the different process. These are the main two tools used for identification of any process widely in the process control. The identification broadly classified into two groups namely open loop identification closed loop identification and closed loop identification, but when compared to open loop identification closed loop identification was accurate and less sensitive to the noise. Closed loop identification was employed widely for the control design and optimization purpose. More over the closed identification was used for identifying for the nonlinear systems.

In chemical industries most of the systems are nonlinear and open loop systems for better control and optimization process those should be controlled and optimized at the certain operating point which was operated at closed loop set point for better control purpose. It was necessary to operate the many chemical systems in closed loop for set point tracking and disturbance rejection purpose. There are many closed loop identification methods [4] available in for identify and control design purpose. Recently relay methods got prominent role for identification and control of the process. Relay methods [1] are based on the fact that from the two key parameters such as ultimate gain and ultimate period the other parameters can easily obtained which does not require any other tests for identification and control design perspective. With precise knowledge we can identify the two key parameters those are used for controller Design purpose In process control community all the chemical systems can be classified into any the following categories such as single input and single output (SISO), FOPTD systems, SOPTD systems, integrating systems, linear systems, non –linear systems, stable systems and unstable systems, multi input and multi output systems (MIMO) [5] based on the dynamics of the process any chemical systems may falls under the above type based on the dynamics of the process. There is enormous amount of work carried out in the area of identification and control of process control systems ever since it was inception [7&9]. There are two types of closed-loop identification [4] test that are widely used in engineering applications, closed-loop step test (Figure1.1) and relay feedback test (Fig 1.2). For the use of a closed-loop step test, the closed-loop controller needs to be specified beforehand for maintaining the closed-loop stability, which may bring difficulty to the closed-loop Configuration since the process is to be identified.

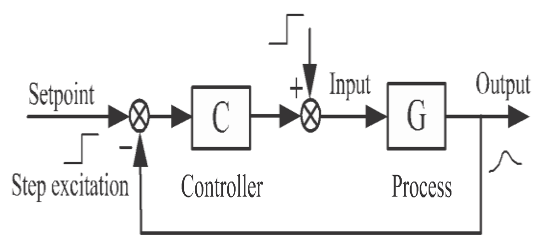


Figure 1.1 Schematic of Closed Loop –Test

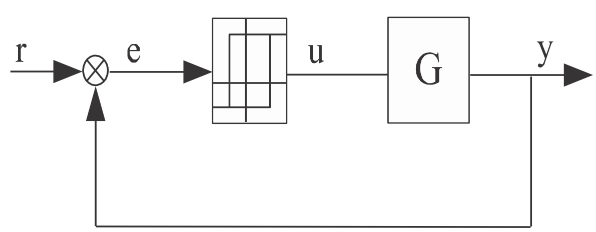


Figure 1.2 Schematic Diagram of Relay Feed-back Test.

Recently one more method was proposed named with subspace method for identification of all the processes such as stable and unstable process. Now days the subspace methods attracted good popularity among the various identification methods. Subspace methods are widely employed for identification and control processes. The rest of the paper is organized as follows section 2 explains the preliminaries about the subspace method and section presents 3 presents the simulation results and section 4 summarizes the Results and discussion and section 5 provides the conclusions.

2. Subspace method

The subspace method, [2&3] the name of which reflects the fact that the linear models can be obtained from row and column spaces of certain matrices calculated from input-output data. Typically, the column space such data matrices contains information about the model, while the row space allows to obtain a state sequence, directly from the input-output data. There is no need for an explicit parametrization. A second advantage is the elegance and computational efficiency of the algorithm of the subspace algorithms. Subspace identification algorithms are based on concepts from system theory, linear algebra and statistics such as projections (orthogonal and oblique Projections) using QR decomposition. Subspace identification methods (SIMs) have gained popularity in the field of system identification since they can identify state space model directly from the input and output data. Subspace methods are based on robust numerical tools such as QR factorization and singular value decomposition (SVD) which makes them attractive from the numerical point of view. The most common classical subspace identification methods are Canonical Variate Analysis (CVA), Multivariable Output Error State Space (MOESP) and Numerical Subspace State Space System Identification (N4SID). In this paper relay and subspace algorithm used to identify the process by taking different case studies from the Literature.

2.1N4SID algorithm

In this research we are incorporating the N4SID (Numerical simulation for subspace and state space algorithm) from the Relay Feedback test and obtain the input and output data making use of the system identification tool box in the MATLAB we are identifying the SISO process and comparing with the actual process which is easiest in terms of the Computational complexity and no priori information is needed. Initially the data from the relay feedback test is generated in the form of the sustained oscillations. the system identification tool box which is shown in the figure 2.1 .the figure 2.1 shows the system identification tool box in this work from the relay feedback test the input and output data is generated which in is shown in the 3.1 this data is fed to the N4SID algorithm to identify the process using the graphical information provides through the system identification shown in the figure 2.4.

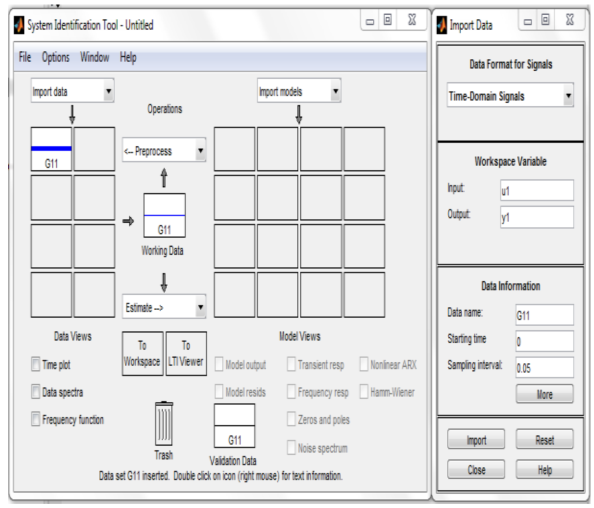


Figure 2.1 system identification Tool Box

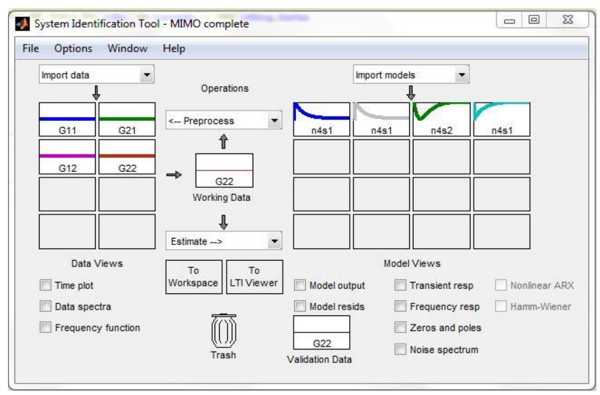


Figure 2.2 system Identification Tool box used for N4SID algorithm

3. **Simulation Results**

In this section different case studies are considered from the literature apply the relay and subspace methods to identify the actual process**.**

3.1 Case study

Consider the process First order and Dead time (FOPTD) given below Equation 3.1 applying the

Relay Feedback test and subspace method we got the following responses shown in the figures . The figure 3.1 shows the sustained oscillations obtained from single relay feedback for the transfer function shown in the Equation 3.1. The actual response for the system is obtained for the given transfer function shown in the figure 3.2 (a) and the identified process using the relay and subspace method is obtained is shown in the figure 3.2(b). From the above figures it is observe red that there is good agreement between the actual process response and identified responses.

$$G11 = \frac{0.126e^{-6s}}{(60s+1)} \quad (3.1)$$

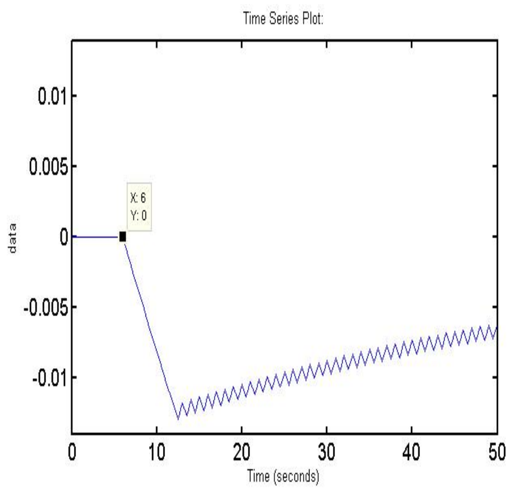


Figure 3.1 Relay Feedback response

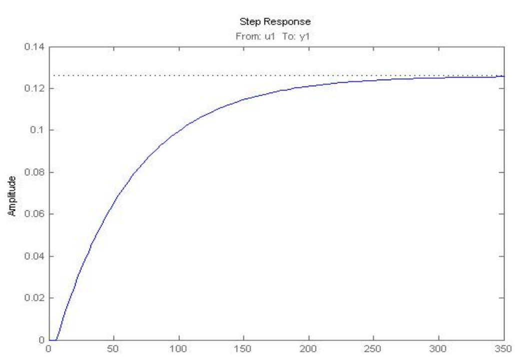


Figure 3.2 (a) actual response

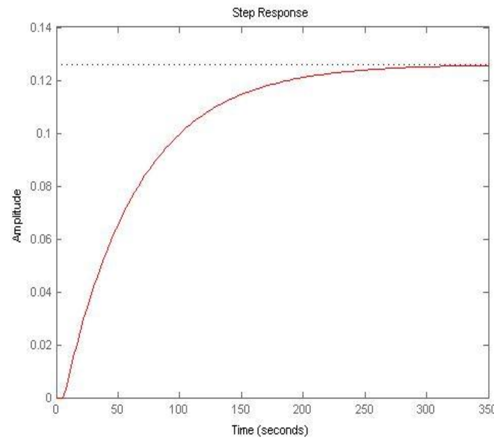


Figure 3.2 (b) identified response from the

And for the identified process a Simple PI Controller is designed shown in the fig 3.3 .the figure shows the response of the Controller for the given set point change shown in the figure. The figure 3. 3 Shows the satisfactory response for the given set point change.

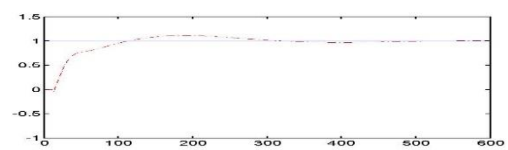


Figure 3.3 controlled Response of the identified process

3.2. Case study

Consider the FOPTD process with numerator with negative symbol the actual process given by the following transfer function given by equation 3.2. The identification process is carried out for the process using the relay feedback test.

$$G22 = \frac{-0.1e^{-3s}}{(35s+1)} \qquad (3.2)$$

The sustained oscillations are generated shown in the figure 3.4. The sustained oscillations as input and

Output data is fed to the system identification tool box shown in the figure and using the N4SID algorithm the

Process is identified with the less knowledge and the identified response is shown in the figure 3.6. There is much accuracy between the actual processes and the

Identified process.

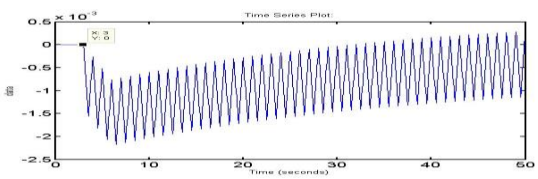


Figure 3.4 Relay feedback Response

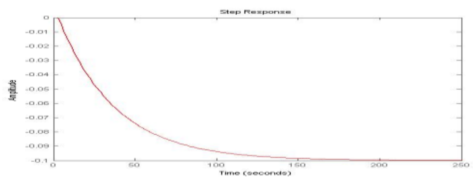


Figure 3.5 Actual Response

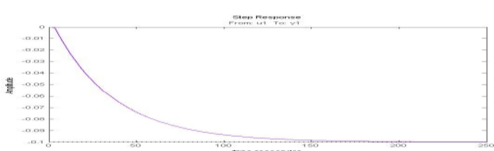


Figure 3.6 Identified Response

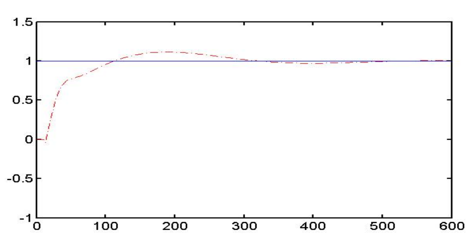


Figure 3.7 controlled response

For the identified process a Simple PI Controller is designed which is shown in the figure 3.7. The figure 3.7 shows the satisfactory response for the identified process which is shown in the figure.

3.3Casestudy

Consider the process with second order plus dead time (SOPTD) by carrying out the above analysis using the Relay Feedback+ Subspace identification method yields the sustained oscillations shows in the figure. The sustained oscillations shows in the figure 3.7 as a result of relay feedback test.

The sustained oscillations as input and output is fed to the system identification tool box shown in the figure 2.1 .the input and output data is fed to the system identification tool box which is show in the figure 2.2 will identify the process with the data obtain from the relay feedback test.

$$G12 = \frac{-0.1016e^{-12s}}{(2160s^2+93s+1)} \quad (3.3)$$

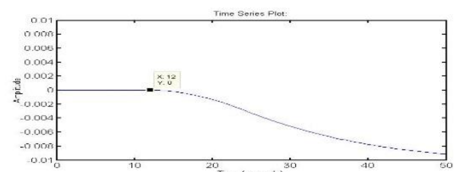
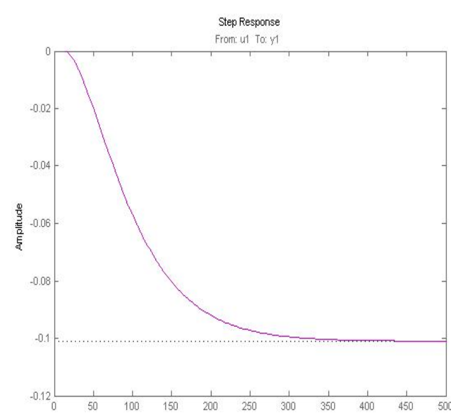


Figure 3.8 Relay Feedback Response

The identified and actual transfer functions are shown in the figure 3.8 and 3.9 respectively. There is a good agreement between the actual process and identified process.



3.9 identified process

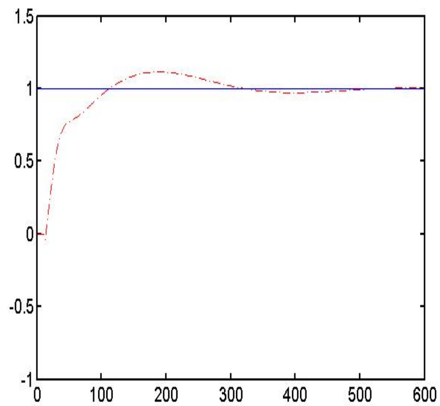


Figure 3.10 controlled response of the process

For the identified process a Simple PID Controller is designed shown in the figure 3.10 the identified process is the second order process with time delay which is having the damping oscillations for this process a simple PID Controller is designed for the set point tracking which shows the satisfactory response even with the simple PID Controller.

4. RESULTS AND DISCUSSTION

In this paper identification and control of the single input and single input and single output is considered as different case studies such as FOPTD, SOPTD process and at first using the relay feedback test the sustained oscillations are generated as shown in the figures [3.1&3.2] .From the sustained oscillations the figures shows the corresponding sustained oscillations which will give as input and output data which is essential next step of identification process. This data is fed to the system identification tool box which are shown in the figures [2.1& 2.2]. The two tool boxes which are shown in the figures will explains the intermediate steps used in the system identification process. For this identification processes here we are incorporating the N4SID (Numerical Simulation for sub space state space method] for identification of the process there are well defined the algorithm is used here. Using the data N4SID algorithm with help of the input and out data the process are identified as shown in the figures [3.4 -3.7] and there is comparisons between the identified process and actual process which are shown in the figures [3.1-3.3] .The figures shows the identified process and actual process are similar. For the identified process using the Z-N Methods simple PI and PID Controllers are designed which are shown in the figures for set point tracking only .the responses which are shown in the figure [3.7-3.10] show the satisfactory figures. In this Paper the two case studies which are considered are the first order and time delay process [FOPTD] and third process is the SOPTD Process.

5 .CONCLUSIONS

The main conclusions that drawn from this work is a simple identification method is proposed in this work for the identification and control which does not require any prior knowledge of the process in terms of the depth mathematical modeling and need of the experimentation data. The simple relay feedback test employed in this work to obtain the process information such as ultimate gain and ultimate process which is fed to the system identification tool box to identify the process which is simple one. For the identified process a simple PI and PID Controller are designed. It can be conclude that the proposed method works well for the identification of the process with less knowledge and may extend for the identification and control of the higher order systems. And unstable systems.

6. REFERENCES

1. Chidambaram & Vivek Sathe Relay Auto tuning for Identification and control, first Edition, Cambridge press.

2. C. Sankar Rao, M. Chidambaram (2014). Subspace identification of transfer function models for an unstable bioreactor, Chemical Engineering Communication, 2014, 1296-1303.

3. C. Sankar Rao, M. Chidambaram (2015). Subspace identification of unstable transfer function models, Indian Chemical Engineer, in press.

4. Tao Liu, Qing-Guowang, Hsia-ping Huang, A tutorial review on process identification from step or relay feedback test.

5. Rames Panda and V.sujatha identification and control of Multivariable systems-Role of Relay Feedback, Introduction to PID controller-Theory, Tuning and Applications to frontier Areas. (2012).

6. Sujatha, V., & Panda, R. C. (2013). Estimation of Parameter for Disturbance Model of 3-by-3 MIMO Process Using Relay Feedback Test. Journal of Modeling, Simulation, Identification and Control, Vol 1, 27-40.

7. C.C. Yu, Auto tuning of PID Controllers: A Relay Feedback Approach, 2nd ed., Springer-Verlag, London, 2006.

8.Shankar Prasad, Yaddanapudi Jaya, Process Identification, Identification and control of Relay-Stabilizable Processes.

9.Advance Control Theory – A Relay Feedback Approack- Somansth Majhi (2009 Cenage Learning Pvt .Ltd).

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