Performance Assessment of Control Loops

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Abstract: ***The main concern of this thesis is to assess control loop performance using minimum variance control by FCOR algorithm in a convenient way by using only routine operating data and comparing the outcomes with an existing algorithm (named PINDEX). Only by determining a performance factor of the feed-back control loop the controller performance could be assessed, even from thousands of control loops in process industries. Minimum variance is the benchmark which indicates attainable minimum variance against the actual variance of the control error. A performance index has been defined as the ratio of minimum variance to actual variance. Where, a performance index value close to 1 indicates good control a value close to 0 indicates poor control. The performance index is always bounded between 0 to1. The performance index calculation algorithm was implemented using MATLAB. A dynamic simulation study was performed using Aspen HYSIS for generating process data and also by SIMULINK. Various cases such as noise corruption, stiction and oscillation were introduced and the aftermath was studied and analyzed. Industrial data from an Ammonia plant (SAFCO) was also analyzed. All the results are compared with previously developed algorithm. This thesis will help to outline a very simple but effective way to detect performance of the controller in process systems.***

Keywords: FCOR, SISO, Performance Index, Feed-back Controlling**.**

1. Introduction

In any chemical complex the foremost endeavor for any chemical engineer is to-make money save money. In process controlling it is very indispensable to get some quick idea that all the controller in control loops working satisfactorily or not. If this checking upon collection of process data could be done within a very short time then the frequency of online checking could be enhanced. So it is very important to take decision about replacing any existing controller or keeping it in accordance with its performance factor. As a relevance to this pragmatic demand, the main objective is to assess control loops performance by applying minimum variance control law, using closed loop process data. According to minimum variance controlling *minimum variance* is the benchmark which indicates attainable minimum variance against the actual variance of the control error. A performance index has been defined as the ratio of minimum variance to actual variance of the control loop. Thus performance index value close to 1 indicates good control while value close to 0 indicates poor control. The performance index value is always bounded between 0 to1. For performance index evaluation, algorithm implemented using MATLAB.

2. About Methodology

A controller performance assessment technique has been developed using the routine operating data for univariate control loops, assuming that control objective is to reduce process variance; this conventional approach is termed as Minimum Variance Control. It is used naturally as the benchmark standard against which current control loop performance is assessed. It has been acknowledged that a system with time delay *d*, a portion of output variance is feedback control invariant and can be estimated from routine operating data. This portion of output variance equals the variance achieved under minimum variance control; thus the method for the estimation of the minimum variance from routine operating data is established. Observed minimum variance for any system means theoretically achievable absolute lower bound of output variance to assess control loop performance. Using minimum variance control as the benchmark does not mean that one has to implement such a controller on the actual process. This benchmark control may or may not be achievable in practice depending on several physical constraints. However, as a benchmark, it provides useful information such as how well the current controller and how much potential there is to improve controller performance further. If the controller indicates a good performance measure relative to minimum variance control, further tuning or re-designing of the control algorithm is neither necessary nor helpful. In this case, if further reduction of process variation is desired, implementation of other strategies such as feed forward control or re-engineering of the process itself may be necessary. On the other hand, if the controller indicates a poor performance measure, further analysis, such as model analysis, robustness analysis, constraint analysis etc may be necessary.

3. Experimental Work done

3.1 Performance Assessment of MATLAB (SIMULINK) model (without stiction block)

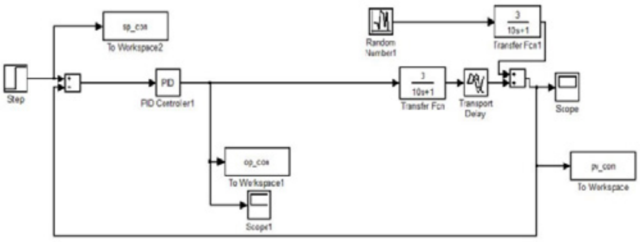

Figure 1. MATLAB Simulink Process block for process data generation.

According to the simulated process Figure 1 above process data is generated. As noise was added into the model process variable shows those uncorrelated noise of the model. Later on plot of process variable with data points with was generated to demonstrate the process behavior. The output of the controller was also observed. Then process data was taken for consideration by both the implemented algorithm and the previously developed one.

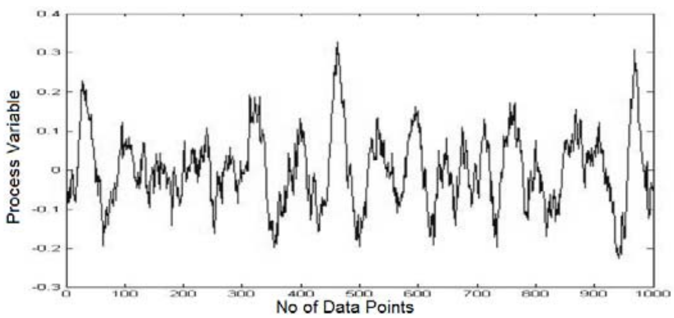

Figure 2. Plot of process variable vs. time

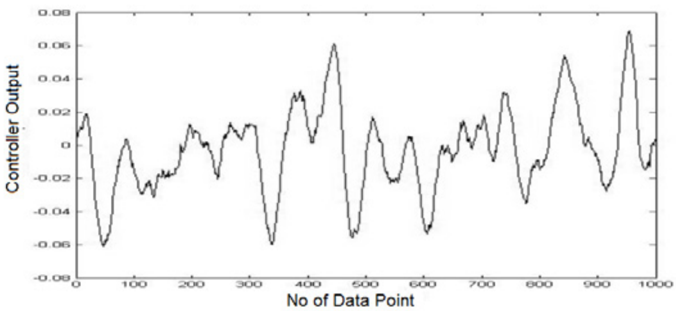

Figure 3. Plot of controller output vs time

Figure 2 shows generated data at different data points. Figure 3 shows controller output at different data points. Controller is basically used to keep the process variable within certain range. To do this controller variable constantly changes with time.

3.1.1 Results

Results found form Pindex and FCOR algorithm are shown below-

Pindex=0.1494

FCOR=0.1503

Performance index is found from study according to minimum variance control law. It is evident from the result that the control loop is performing poorly (as the index values are close to 0). Both Pindex and FCOR algorithm show similar results. It assures that developed algorithm works nicely to evaluate the performance index of this simulated process without valve stiction of the controller. Afterwards, simulation was also considered using the stiction model in the system to substantiate the proper functioning of the developed algorithm.

3.2 Performance Assessment of MATLAB model (with stiction block)

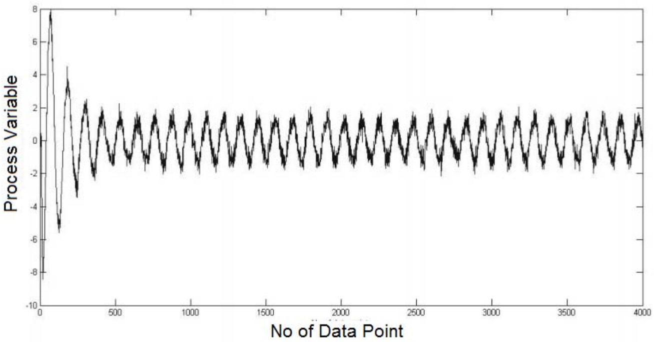

Figure 4. Plot of process variable vs. time along with valve stiction to the previous SIMULINK model.

Figure 4 shows the generated data with number of data point. Stiction model was used in the simulated simulink process, which caused the process variable to oscillate. Above figure demonstrate that oscillation pattern of the process clearly.

3.2.1 Results

Results fund form Pindex and FCOR algorithm are shown below-

Pindex=0.1500

FCOR=0.1231

Performance index is found from study according to minimum variance control law. This time it is also evident that the control loop is performing poorly. As performance index of both loop is less than 0.5 or close to zero. Both Pindex and FCOR algorithm show similar results with the assurance of the proper functioning of the developed algorithm.

3.3 Performance Assessment of ASPEN HYSIS Simulated process

Simulation process of a distillation column was demonstrated by HYSIS modeling, it was about an overhead circuit for a distillation column using more detail than just the condenser module. Column pressure control was achieved primarily by bypassing some of the overhead vapor around the condenser. PIC-101 was used to control the overhead accumulator pressure using the bypass. The top tray pressure was controlled by PIC-100, which essentially maintains a constant pressure drop between the top tray and the overhead accumulator. If the system overpressures, PIC-102 vents to flare. The reflux rate was on flow control, with the overhead accumulator level being controlled by the product rate. There was a temperature control at the bottom of the column, and level control for the sump.

3.3.1 Performance Assessment of Different Loops

Figure 5 shows different process data generated by the simulation developed in Aspen HYSIS. PIC-100 controlled the distillate flow rate. Oscillation was added to this controller by a transfer function block. This stream was cooled by a heat exchanger and then feed to the condenser. From graph and calculated index it is clearly evident that the loop was performing very badly. PIC-101 also controlled a part of distillate flow stream. LIC-100 controlled the level of condenser. Valve stiction was added to this controller. FIC-100 controls the reflux ratio of the distillation column. Though there were some noise in the loop but the controller is performing satisfactorily. TIC-100 controlled the heat duty of the reboiler. This loop was very sensitive as this controlled the different temperature of the distillation column. From result it is evident that controller is performing according to desire. Level indicator controller named by LIC-101 was also performing well.

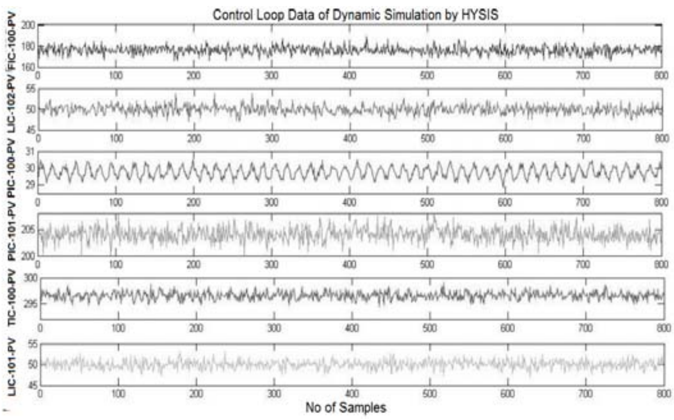

Figure 5. Plot of Controlled Variable Data of Simulated distillation column by HYSIS.

3.3.2 Results

According to minimum variance control law, table 1 shows that control loops FIC-100, LIC-101, LIC-102, PIC-101, and TIC-100 are performing satisfactorily as their performance indexes are closed to 1 for the considered distillation column. But performance index of PIC-100 loop is very much less than 0.5. This indicates that the controller is performing badly. This is the causal outcomes, as at this control loop oscillation was introduced while simulation was performed. This is a significant demonstration of the developed way that it will work relevantly even in real process with the existing oscillations in system.

Table 1. Results showing performance index of different control loops of HYSIS simulation.

ControllerAlgorithm	FIC-100	LIC-101	LIC-102	PIC-100	PIC-101	TIC-100
Pindex	0.9927	0.9948	0.9954	0.2096	0.9771	0.9177
FCOR	0.9831	0.9701	0.9925	0.1998	0.9965	0.9297

Above table clearly shows the compatibility of the FCOR algorithm for any real process simulation with oscillation and noise inherent with the process systems.

3.4 Process Data Analysis of SAFCO Plant

Process data from SAFCO was tested against both of the control loop performance assessment algorithms. Figure 6 shows 21FIC105.PV control loop data for a flow control loop as an example of several loops in that fertilizer plant.

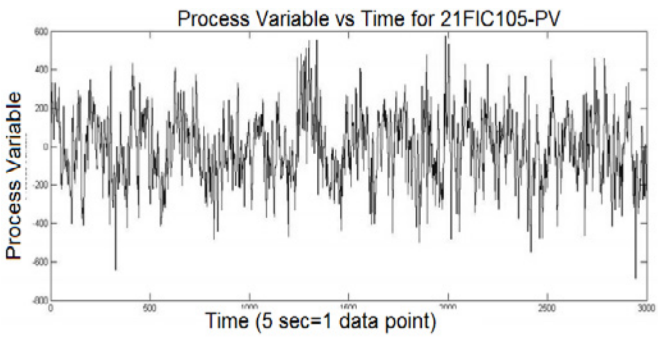

Figure 6. Plot of process variable vs time

3.4.1 Results

It can be seen from the table 2 is that there are 3 flow indicator controllers and rest of the controllers are mainly pressure indicator controller. If all the controllers are analyzed then it can be seen that flow indicator controller is performing well than the pressure indicator controller in SAFCO. It can also be seen that pindex result shows that some of the index results are very close to zero which means the controller is performing very poorly. This completely supports the developed algorithm, which strengthens the pragmatic convenient use for any real process plant like fertilizer cpmplex.

Table 2. Results showing performance index of different control loops of the SAFCO plant

Loop	Pindex	FCOR
21FIC114.PV.	1.5385e − 007	0.1694
21PDIC101.PV.	0.0048	0.0041
21PIC108.PV.	0.01	0.0118
21PIC201.PV.	5.0859e − 005	0.0071
21PIC402.PV.	0.0090	0.0079
21PIC734A.PV	1.9175e − 004	0.3169
21PIC734B.PV.	2.9737e − 005	0.3187
21PIC741.PV.	1.9175e − 004	0.3169
21PIC742.PV.	1.9175e − 004	0.3169
22PIC117.PV.	0.1404	0.1345
23PIC411.PV.	9.0615e − 006	0.1590
21FIC102.PV.	2.6911e − 004	0.0212
21FIC105.PV.	0.0063	0.0061
21FIC110.PV.	0.5122	0.4938
21PIC108.PV.	0.0658	0.0139
21PIC201.PV.	0.0129	0.0139

4. Outcomes and Findings

This project is basically based on closed loop univariate system for single input and single output (SISO) process to find out whether is the existing controller is working satisfactory or not. By comparing the performance index of the target loops with the theoretical standard the plant operator can identify the faulty loops only by analysis the routine operating data. Future work could be extended to multivariate system for multiple inputs and multiple outputs (MIMO) process. Topics of further research adjunct to adjoincy matix with Minimum variance control, Controller Auto-Tuning Based on Control Performance Monitoring, Online performance assessment, Automation of the controller diagnosis. By only analyzing closed loop data, unsatisfactory loops can be identified easily from thousands of control loops. In modern process systems there are strong incentives for automated control performance monitoring (CPM) and it's assessments for process control loops or the controller. Although several CPM techniques have been applied successfully already, they also have several shortcomings. First, most of the existing techniques assess control system performance but do not diagnose the root cause of the poor performance. A second shortcoming is that assessment formulation for MIMO process is complicated and usually restricted to unconstrained control systems, monitoring strategies for MPC systems are a subject of current research all over the world.

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