LabVIEW and Internet based Sliding Mode Control of a Variable Structure System through Internet

S.Harivardhagini
CVR college of Engineering
Vastunagar, Andhra Pradesh
India

A.D.Rajkumar, PhD
CVR College of Engineering
Vastunagar, Andhra Pradesh
India

ABSTRACT

This paper deals with certain aspects of operation of a third order Variable Structure System using Sliding Mode Control (SMC). SMC is applied to the process plant using LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench). The process plant and its control are simulated using LabVIEW 2011 and the results are compared with conventional PID controller. It is found that the settling time of the system obtained with SMC is much less than that obtained by conventional PID controller. The whole process is monitored and controlled through internet.

Keywords

Variable Structure Systems, Sliding Mode Control, LabVIEW.

1. INTRODUCTION:

Variable Structure systems contain several subsystems whose parameters can be changed or switched according to the state of the system [1]. The gain of the system can be changed or the transfer function of the system itself can be changed in such systems. SMC is a special type of control used that is used for Variable Structure systems. Variable Structure systems with SMC was first proposed and elaborated in early 1950's by Emelynov [2], Utkin [3] and Itkis [4]. The process is converted into state space form (Phase variable form) to make it suitable for applying SMC. The state at which the structure changes causing discontinuity surfaces in phase plane is called switching surfaces. In this paper SMC is applied to a third order system [5] and the control law is obtained. The complete simulation is done through LabVIEW 2011 which is more hardware friendly. LabVIEW is a highly productive development environment that engineers and scientists use for graphical programming and unprecedented hardware integration to rapidly design and deploy measurement and control systems. The objective of this paper is to present the response of the system through two different control strategies. The response is first obtained using conventional PID control and compared with SMC. In addition the results are viewed and controlled via internet using web publishing tool.

2. SLIDING MODE CONTROL

Consider a second order system [6] system

$$\ddot{x} = -ux \quad (1)$$

Having structures defined by $u = \alpha_1^2$ and $u = \alpha_2^2$ with $\alpha_1^2 > \alpha_2^2$. If the phase portrait of the above is drawn we get concentric ellipses.

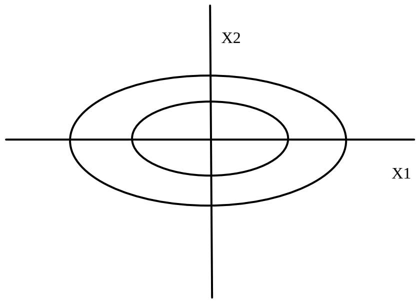


Figure 1: Phase portrait of $u = \alpha_1^2$

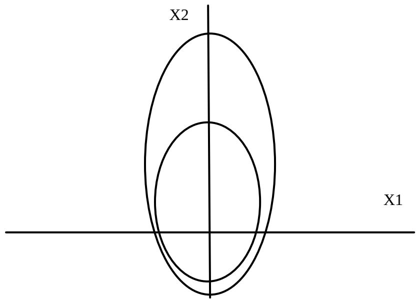


Figure 2: Phase portrait of $u = \alpha_2^2$

Hence the system is not asymptotically stable. To make it stable we introduce a switching logic

$$u = \begin{cases} \alpha_1^2, & \ddot{x}\dot{x} < 0 \\ \alpha_2^2, & \ddot{x}\dot{x} > 0 \end{cases} \quad (2)$$

The switching logic along with a control law makes the system converge towards the origin. The system becomes asymptotically stable.

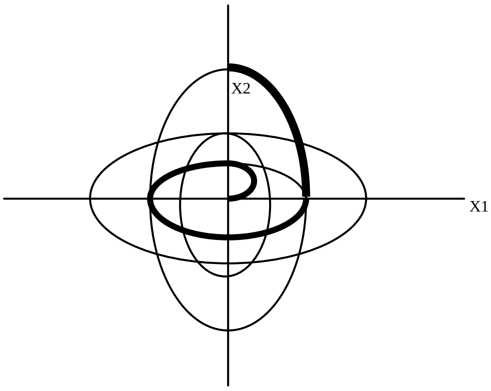
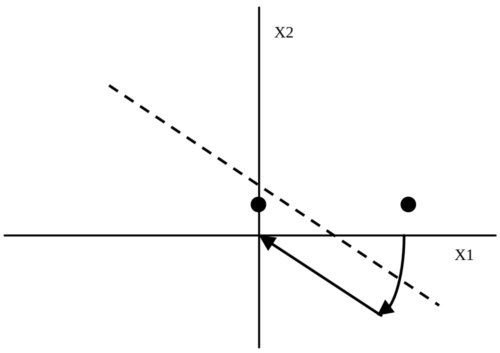


Figure 3: Asymptotically stable system

After the system reaches the origin, it is forced to slide along a surface called SLIDING SURFACE. The dotted line shown in the figure 4 is the sliding surface.



Sliding Surface

Figure 4: Trajectory of the system after application of SMC

3. VARIABLE STRUCTURE SYSTEM IN PHASE CANONICAL FORM

The design of SMC for zeroing the output $y = x1$ [7]of the following system

$$\dot{x_1} = x_{i+1}, \quad i = 1,2, n-1 \qquad (3)$$

$$\dot{x_n} = -\sum_{i=1}^{n} a_i x_i + f(t) + u \qquad (4)$$

Where

u is the control input, $f(t)$ is the disturbance, a_i are constants.

Assuming u is a function of the state vector, x undergoes discontinuities on some plane at $= 0$, where

$$s = \sum_{i=1}^{n} c_i x_i, \quad c_i = const, c_n = 1 \qquad (5)$$

Then the velocity vector undergoes discontinuities in the same plane. As explained in the above example the trajectories are directed towards the sliding surface $s = 0$. The desired Sliding mode is achieved by choosing proper values ofc_i, then a discontinuous be in charge of is found which ensures existence of Sliding mode at every point of the surface $s = 0$.Finally a control law that must steer the state to the Sliding surface. These steps are applied to Time Invariant Process. Let then parameters of the process a_i be constant and $f(t) = 0$. The state is moved to zero. Control u is chosen as a piecewise linear function of x with discontinuous coefficients

$$u = \sum_{i=1}^{k} \psi_i X_i - \delta_0 sgn\, s, \qquad 1 \le k \le n-1 \qquad (6)$$

$$\psi = \begin{cases} \alpha_i \ if\ x_i s > 0 \ \ sgns = \begin{cases} +1 & if \quad s > 0 \\ -1 & if \quad s < 0 \end{cases} \\ \beta_i if\ x_i s > 0 \ \ \alpha_i \ , \beta_i, \delta_0 \ are\ constants \end{cases} \qquad (7)$$

A necessary and sufficient condition for Sliding surface to exist is [8],[9] is

$$\alpha_i \ \ge c_{i-1} - a_i - \ c_i c_{n-1} + c_i a_n \qquad (8)$$

$$\beta_i \le c_{i-1} - a_i - \ c_i c_{n-1} + c_i a_n, \ i = 1 \ldots . k, c_0 = 0 \qquad (9)$$

$$\frac{c_{i-1} - a_i}{c_i} = \ c_{n-1} - a_n, \qquad i = k+1, \ldots . n-1 \qquad (10)$$

Hence coefficients c_i needed for the desired Sliding mode are to be chosen based upon the above equalities.

4. DESCRIPTION OF SYSTEM UNDER STUDY

The system chosen is a level controller system to which VSC is applied. The level controller system consists of a tank which has its input flow controlled by a control valve. The VSC is applied to the control valve. The operation is inherently discontinuous and non-linear. The process is subjected to PID control and VSC separately and the results are compared. The block diagram of the system under study for each of the controllers are shown in figure 5 and 6.

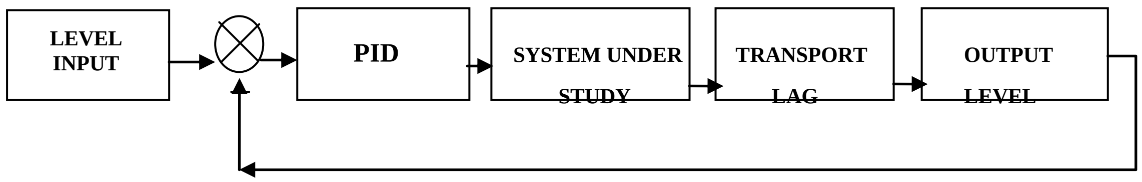


Figure 5: Level control system with PID control

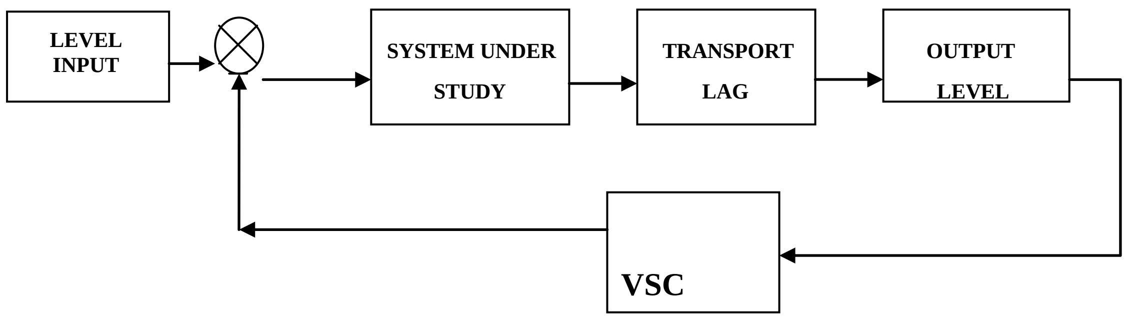


Figure 6: Level control system with VSC control

The transfer function of a third order level control process is given by [5]

$$\frac{Y(S)}{M(S)} = \frac{-12.72S+101.8}{S^3+17.24S^2+81.5S+60} \quad (11)$$

The transfer function is converted to canonical form

$$\dot{x} = \begin{bmatrix} 0 & 0 & -60.6 \\ 1 & 0 & -81.51 \\ 0 & 1 & -17.24 \end{bmatrix} X + \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} u \quad (12)$$

$$y = [0 \quad -12.73 \quad 321.26] X \quad (13)$$

From the equations (6) and (7) the control law is generated

$$u = \psi_1 X_1 + \psi_2 X_2 + \psi_3 X_3 \quad (14)$$

Where

$$\psi_1 = \begin{cases} \alpha_1 & sX_1 > 0 \\ \beta_1 & sX_1 < 0 \end{cases}$$

$$\psi_2 = \begin{cases} \alpha_2 & sX_2 > 0 \\ \beta_2 & sX_2 < 0 \end{cases}$$

$$\psi_3 = \begin{cases} \alpha_3 & sX_3 > 0 \\ \beta_3 & sX_3 < 0 \end{cases}$$

From the equation (5) the sliding surface is given by

$$s = c_1 X_1 + c_2 X_2 + c_3 X_3 \quad (15)$$

The values of the parameters are obtained as follows

$\alpha_1 = -0.01$, $\beta_1 = 0.5$, $c_1 = -0.65$

$\alpha_2 = -0.1$, $\beta_2 = 0.1$, $c_2 = 3.4$

$\alpha_3 = 1$, $\beta_2 = 0.1$, $c_3 = 1$

5. RESULTS AND CONCLUSION

The level process is controlled using PID control and then using VSC. The PID controller was tuned and the following values were found.

$K_p = 1.968$

$K_i = 0.042$

$K_d = 0.6299$

Where,

K_p is the Proportional gain of the controller

K_i is the Integral gain of the controller

K_d is the Derivative gain of the controller

The block diagram and the front panel diagram are shown in figure7 and 8 respectively.

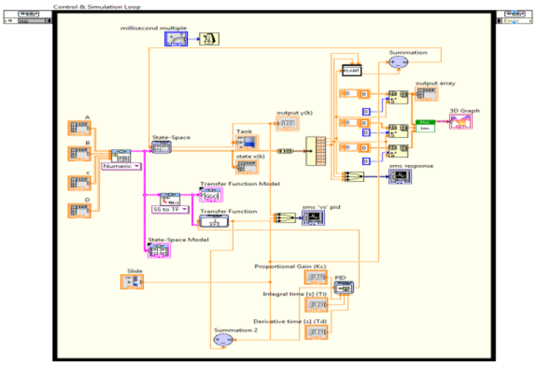


Figure 7: Block diagram of VSC controlled level process

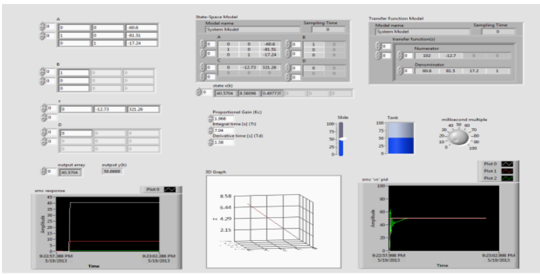


Figure 8: Front panel of VSC controlled level process

The results were monitored and controlled through internet using WEB Publishing Tool in LabVIEW 2011.

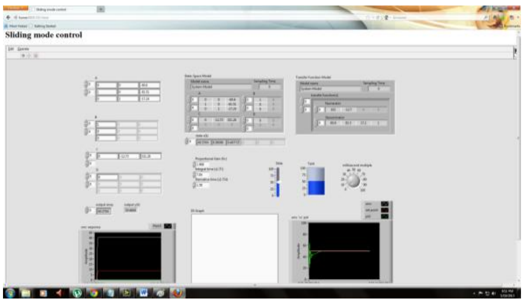
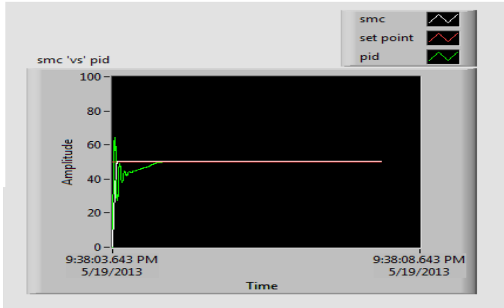


Figure 10: Comparison of the output for both the controllers for a setpoint of 50

Figure 9: VSC through internet

On comparing the output, VSC control had a lesser Rise time and low Settling time than PID control. Also when a disturbance is generated in the input VSC had better disturbance rejection as compared with PID control.



6. REFERENCES

[1] Vadim I Utkin " Survey paper on Variable Structure System with Sliding modes", IEEE Transactions on Automatic Control, Vol No:2, April 1977.

[2] S.V.Emelyanov "Use of Non Linear Corrective Devices of switch type to improve quality of Second Order Automatic Control System", Automate. I Telemekh, Vol 20, No:7, 1959 (in Russian).

[3] Vadim I Utkin " Survey paper on Variable Structure System with Sliding modes", IEEE Transactions on Automatic Control, Vol No:2, April 1977.

[4] S.V.Emelyanov "Use of Non Linear Corrective Devices of switch type to improve quality of Second Order Automatic Control System", Automate. I Telemekh, Vol 20, No:7, 1959 (in Russian).

[5] Second Order Automatic Control System", Automate. I Telemekh, Vol 20, No:7, 1959 (in Russian).

[6] Hazim.H.Tahir, A.A.A. AL-Rawi "Variable Structure Control Design of process plant based on Sliding Mode Approach" Proceedings of 25th Chinese Control Conference, 7-11th August, 2006.

[7] B. B. Musmade, R. K. Munje, B. M. Patre "Design of Sliding Mode Controller to Chemical Processes for Improved Performance", International Journal of Control and Automation Vol. 4 No. 1, March 2011

[8] E.A.Barbhashin andV.A.Tabueva "A method of stabilizing Third Order Systems with large gains", Automat. Remote Contr., Vol I, No 10,.pp. 1215-1222, Vol II, No. 5 ,.pp562-567, 1963.

[9] S.V.Emelyanov et.al., "Theory of Variable Structure Systems"(in Russian), Moscow: Nauka, 1970.

[10] S.V.Emelyanov et.al., "On Design of Variable Structure Control Systems for control of Linear plants" Eng. Cybern., No.2,pp. 69-78,1963.