Design of a Sliding Mode Controller to Eliminate the Limit Cycle in Chaotic Van der Pol System in Comparison with State Feedback Controllers

Shahzad Ahmad [1],Abdul Rehman Yasin [2], Adrian Plesca [3], Usman Younis[1]
[1]Department of Electrical Engineering, Information Technology University Lahore, 54000, Pakistan,
[2]Department of Electrical Engineering, The University of Lahore, 54590, Pakistan,
[3] Electrical Engineering Department, Gheorghe Asachi Technical University of Iasi, Romania.
Email: engrshahzad2000@gmail.com

***Abstract*— In this paper sliding mode controller is designed in comparison with the linear state space feedback controllers namely the pole placement controller and linear quadratic regulator to eliminate the chaotic limit cycle oscillations in Van der Pol system induced by an external sinusoidal excitation in order to avoid failure in physical structures. The controller design is based on the mathematical model of the Van der Pol oscillator presented in this paper. The sliding mode controller is robust in chaotic motion as it achieves global asymptotic stability about an unstable equilibrium point which is the origin in contrast to the state feedback controllers which fail to achieve asymptotic stability about the origin. The lyapunov stability of the system is proved to ensure that the system hits the sliding surface in a global asymptotic sense. The sliding dynamics of the sliding surface is proved to exhibit finite time convergence to the origin. The dynamics of the sliding surface is examined for three different conditions of sliding surface coefficients. The validity of the design is verified through MATLAB /Simulink based simulations.**

***Keywords*— Sliding mode control; Lyapunov stability; Global asymptotic stability; State feedback; Limit cycle; Nonlinear;**

REFERENCES

[1] Dilmi S, Bouzouia B. Improving performance for nonlinear aeroelastic systems via sliding mode controller. Arab J Sci Eng 2016; 41(9): 3739-3748.
[2] Grudziński K, Żebrowski JJ. Modeling cardiac pacemakers with relaxation oscillators. Physica A 2004; 336(1): 153-162.
[3] Gois SR, Savi MA. An analysis of heart rhythm dynamics using a threecoupled oscillator model. Chaos Solıton Fract 2009; 41(5): 2553-2565.
[4] Bradley M, Alarcón E, Feely O. Control of limit cycle oscillations in a multiple-sampled digitally controlled buck converter. Int J Circ Theor App 2015: 43(6): 691-708.
[5] Abdullahi AM, Mohamed Z, Muhammad M, Bature AA. Vibration and tip deflection control of a single-link flexible manipulator. International Journal of Instrumentation and Control Systems 2013; 3(4): 27-17.
[6] Lazzouni SA, Siewe MS, Kakmeni FM, Bowong S. Slow flow solutions and chaos control in an electromagnetic seismometer system. Chaos Solıton Fract 2006; 29(4): 988-1001.
[7] Tanaka MC, de Macedo Fernandes JM, Bessa WM. Feedback linearization with fuzzy compensation for uncertain nonlinear systems. Int J Comput Commun 2013; 8(5): 736-743.
[8] Canudas-de-Wit C, Rubio FR, Corchero MA. D-OSKIL: A new mechanism for controlling stick-slip oscillations in oil well drill strings. IEEE T Contr Syst T 2008; 16(6): 1177-1191.
[9] Mohamed M, Karim T, Belghith S. Chaos suppression in forced van der pol oscillator. International Journal of Computer Applications 2013; 68(23).
[10] Liu D, Yamaura H. Chaos control of a φ 6-van der pol oscillator driven by external excitation. Nonlinear Dynam 2012; 68(1): 95-105.
[11] Li SY. Chaos control of new Mathieu–van der pol systems by fuzzy logic constant controllers. Appl Soft Comput 2011; 11(8): 4474-4487.
[12] Solak E, Morgül Ö, Ersoy U. Observer-based control of a class of chaotic systems. Physics Letters A. 2001; 279(1): 47-55.
[13] Wang HH, Krstic M. Extremum seeking for limit cycle minimization. IEEE T Automat Contr 2000; 5(12): 2432-2436.
[14] Krstić M, Wang HH. Stability of extremum seeking feedback for general nonlinear dynamic systems. Automatica 2000; 36(4): 595-601.
[15] Maccari A. Vibration control for the primary resonance of the van der Pol oscillator by a time delay state feedback. Int J Nonlinear Mech 2003; 38(1): 123-131.
[16] Ahmad S, Abbas G, Yasin AR, Farooq U. Elimination of limit cycle in unexcited van der pol system using fuzzy supported state space controllers. In: Open Source Systems & Technologies; 15–17 Dec 2015; Lahore. Pakistan, IEEE. pp. 114-121.
[17] Repperger DW, Buckholtz K, Daniels M. A study on the stabilization of the van der Pol limit cycle. Int J Syst Sci 2004; 35(11): 661-669.
[18] Guckenheimer J. Dynamics of the van der pol equation. IEEE T Circuits Syst 1980; 27(11): 983-989.
[19] Dumitrescu I, Bachir S, Cordeau D, Paillot JM, Iordache M. Modeling and characterization of oscillator circuits by van der pol model using parameter estimation. Journal of Circuits, Systems, and Computers 2012; 21(05): 1250043.
[20] Wang D, Zhou S, Yu J. The existence of closed trajectory in the van der pol oscillator. In Communications, Circuits and Systems and West Sino Expositions; 29 June-1 July 2002; Chengdu. China: IEEE. pp. 1629 vol.2.