Time Delay Feedback Control based Chaos Stabilization in Current Mode Controlled DC Drive System

Selçuk Emiroğlu, Yılmaz Uyaroğlu

***Abstract*— This paper focuses on delay feedback control scheme to eliminate chaos in a current mode controlled DC drive system. The delay feedback method is applied for the current mode DC drive system which exhibits chaotic behavior for some parameter variations to control the chaos in DC drive system. Firstly, the change of system behavior from normal to chaotic operation is shown by changing some parameters. To control the chaos in current mode DC drive system, the controller designed based on time delay feedback control method is applied to DC drive system which works in chaotic regime. It is showed that the behavior of system changes from chaotic regimes to normal operation by applying the time delay feedback control.**

***Index Terms*— Chaotic systems, chaos control, nonlinear phenomena in power electronics, time delay feedback control.**

I. INTRODUCTION

Power electronics is a new and developing field used in real life and related with many industrial applications. Recently, power electronics provides to develop the technology for many purposes [1]. Power sources used in many industrial applications are wanted to provide high efficiency, small volume and constant (stable) output voltage. Because these specifications cannot be provided with linear devices, switched mode power supply is recently resulted to develop. So, switch mode converters are used to begin in many applications of power electronics [2]. In 1984, nonlinear phenomena occurred in power electronics circuits were firstly researched by Brockett and Wood [3]. Nonlinear behavior of power electronics circuit due to feedback control of switch and variety of dynamic behavior is shown [4]. For control of chaos which occurs in converters, many control methods are proposed such as OGY [5, 6], time delay feedback control [7]. In many study, chaos control methods are applied to feedback controlled DC-DC converters [8].

Feedback controller is designed to control chaotic system via time delay feedback control approach. Simulation results show that the time delay feedback controller can regulate the chaotic regime effectively.

The rest section of this paper is organized as follows. In system description section, the current mode controlled DC chopper-fed PM DC drive system is described. In the chaos control section, the controller is designed based on time delay feedback control. In another section, numerical results are given and discussed graphically. Finally, conclusions are given.

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II. DESCRIPTION OF CURRENT MODE DC DRIVE SYSTEM

Existing of chaos in a current mode controlled DC chopper-fed PM (Permanent Magnet) DC (Direct Current) drive which assumes to work in continuous conduction mode has been investigated in this study. Power electronics circuits may have nonlinearity for many reasons [1].

- The semiconductor switching devices have nonlinear DC characteristics such as BJT, MOSFET, diode, thyristor.
- The control circuits contain nonlinear components such as PWM, multiplier, comparator and digital controller.
- They may have nonlinear capacitance or inductance.

Diagram of current mode controlled DC drive [9] and equivalent circuit of voltage mode controlled DC drive are shown in Fig. 1.

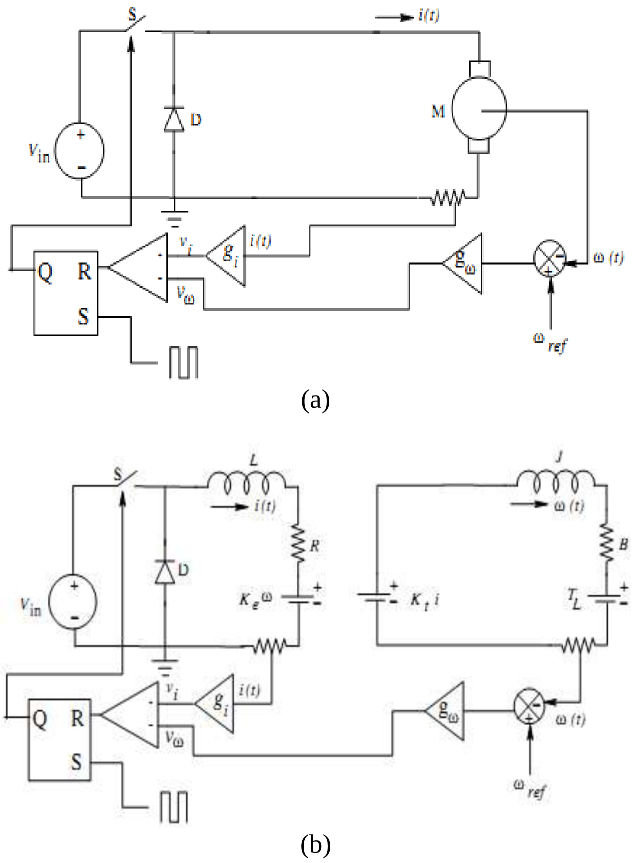

Figure 1. (a) Diagram of voltage mode controlled DC drive
(b) Equivalent circuit of current mode controlled DC drive

The circuit of DC drive system is divided into two parts: power and control parts. Power part consists of power switching element and diode.

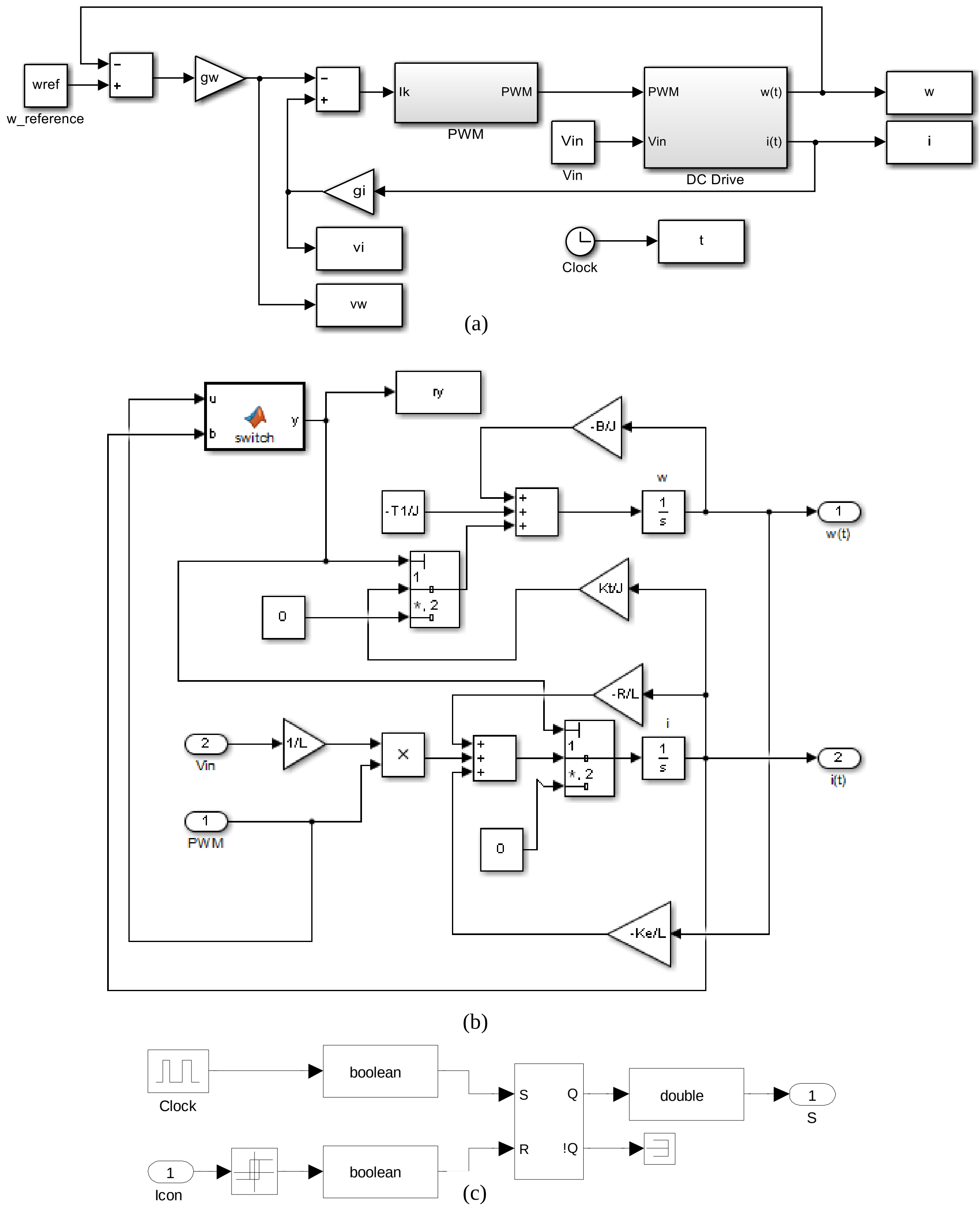

Figure 2. Matlab-Simulink model of DC drive system (a), Mathematical model of power circuit of DC drive system (b), PWM generator (c)

Control part consists of angular velocity and current controller. Controller output pulses are brought into comparator which is compared to constant period (T) pulse signal.

If the speed error amplifier gain and current amplifier gain are gω and gi respectively, the control signals for speed and current vω(t) and vi(t) can be obtained as:

$$v_{\omega}(t) = g_{\omega}(\omega_{ref} - \omega(t))$$
$$v_i(t) = g_i i(t) \qquad (1)$$

where *i(t)* armature current of the dc motor, *ω(t)* rotor speed of the DC motor;, ω_{ref} reference speed of the dc motor.

Then, after v_{ω} and v_i are compared with comparator, comparator outputs send the pulse to the reset of an – latch. The power switch is controlled by this – latch which is set by clock pulses of period.

According to the state of switch or the output of SR latch, the system state equations can be expressed with two groups by following:

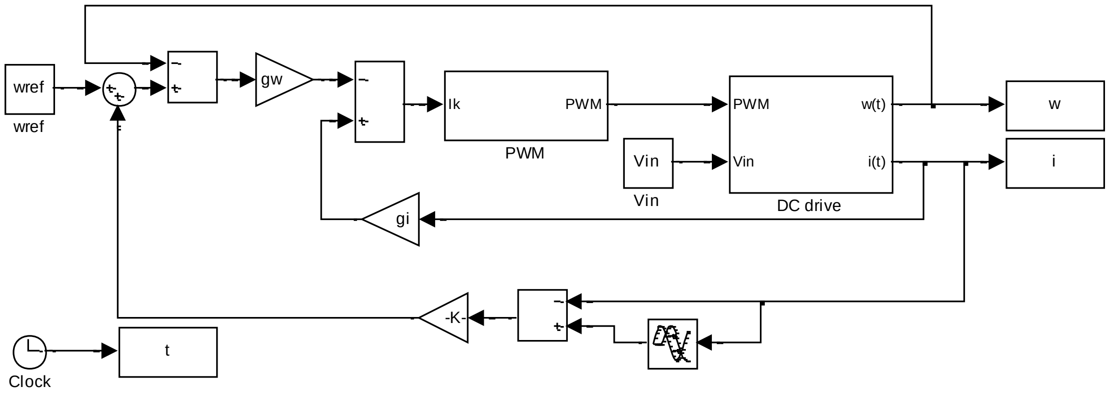

Figure 3. Simulink model of controlled DC drive system

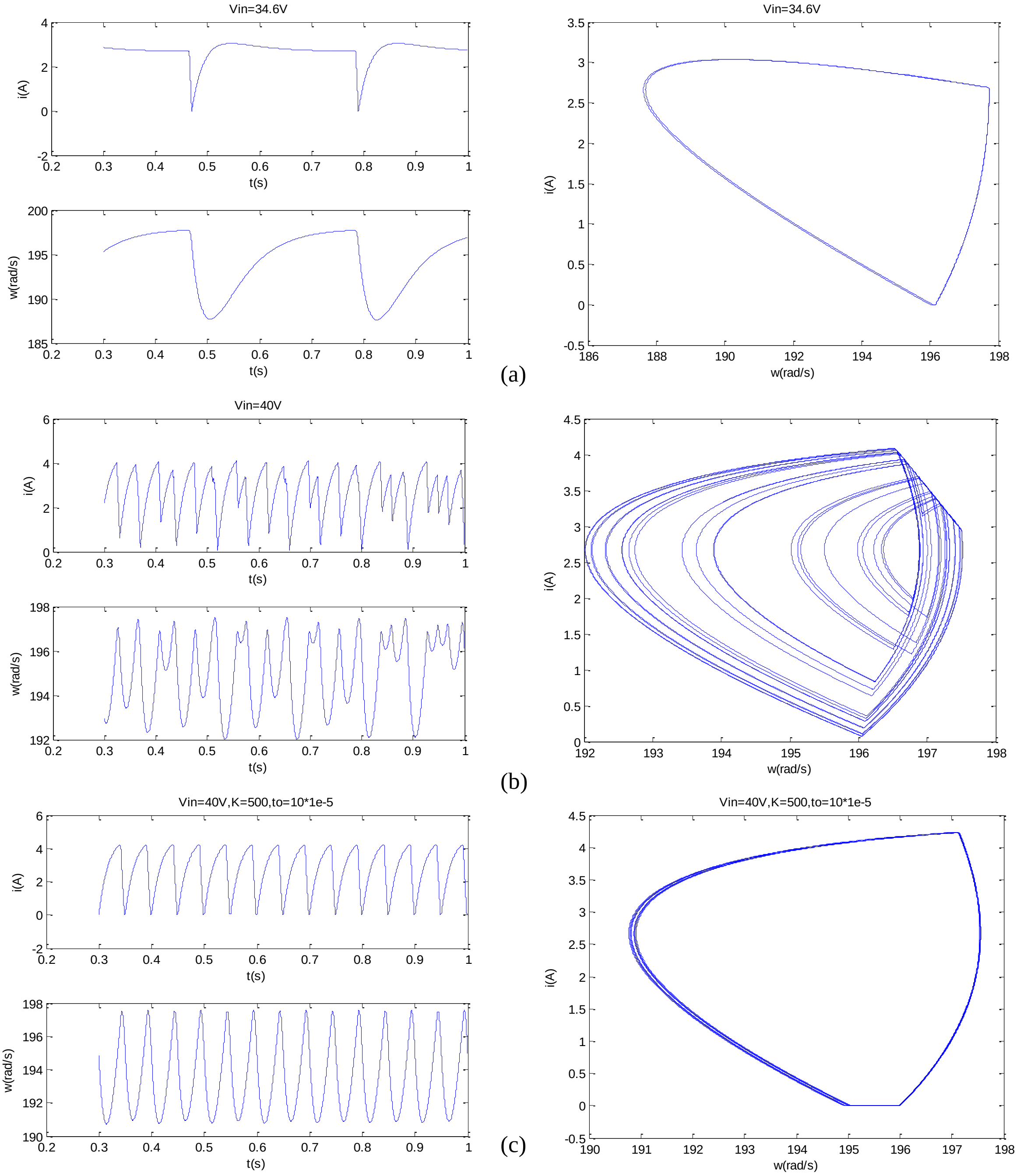

Figure 4. Time series and phase spaces of normal operation (a), chaotic operation (b) and controlled system (c)

When SR latch is set,

$$\frac{d}{dt}\begin{pmatrix}\omega(t)\\ i(t)\end{pmatrix}=\begin{pmatrix}-B/J & K_T/J\\ -K_E/L & -R/L\end{pmatrix}\begin{pmatrix}\omega(t)\\ i(t)\end{pmatrix}+\begin{pmatrix}-T_l/J\\ V_{in}/L\end{pmatrix} \quad (2)$$

When SR latch is reset in continuous conduction mode,

$$\frac{d}{dt}\begin{pmatrix}\omega(t)\\ i(t)\end{pmatrix}=\begin{pmatrix}-B/J & K_T/J\\ -K_E/L & -R/L\end{pmatrix}\begin{pmatrix}\omega(t)\\ i(t)\end{pmatrix}+\begin{pmatrix}-T_l/J\\ 0\end{pmatrix} \quad (3)$$

When SR latch is reset in discontinuous conduction mode,

$$\frac{d}{dt}\begin{pmatrix}\omega(t)\\ i(t)\end{pmatrix}=\begin{pmatrix}-B/J & 0\\ 0 & 0\end{pmatrix}\begin{pmatrix}\omega(t)\\ i(t)\end{pmatrix}+\begin{pmatrix}-T_l/J\\ 0\end{pmatrix} \quad (4)$$

where R is armature resistance; L is armature inductance; V_{in} is DC supply voltage; K_E back-EMF constant; K_T is torque constant; B is viscous damping; J is load inertia; T_l is load torque.

III. Control of Chaos In Current Mode DC Drive System

Firstly, Ott, Grebogi and Yorke proposed a control method called as OGY [19] method for control of chaotic systems. By applying OGY method to chaotic systems, many chaos control methods proposed and applied to control the chaos in chaotic systems [5, 6]. Pyragas [6] showed that chaotic behavior could be controlled by applying delayed feedback control method. *F(t)* obtained that the difference between current value of system variable *y(t)* and its τ seconds previous multiplied by constant *K*, where *K* is feedback gain as following expression.

$$F(y,t)=K[y(t-\tau)-y(t)] \quad (5)$$

The structure of the Simulink model for the converter controlled using delayed feedback control method is given in Fig. 3. As can be seen from the Fig. 3, ω_{ref} can be written in (6) for controlled system.

$$\omega_{ref}(t)=\omega_{ref}+K[\omega(t-\tau)-\omega(t)] \quad (6)$$

The DC drive system modelled by state equations is constructed in MATLAB-Simulink. Using Simulink model (Fig. 2), time series and phase space is obtained by varying input voltage in both normal and chaotic regime. In order to control the chaos, delayed feedback controller is added to the DC drive system in chaotic regime. After the controller is activated, the DC drive system will works at normal operation.

IV. Numerical Results

To illustrate the effectiveness of approach, computer simulations are carried out. The simulation parameters are based on the values of a practical DC drive system and taken from [10, 11].

Angular velocity and current waveforms under normal conditions of DC drive system are given Fig. 4a with $V_{in}=34.6$. As can be seen Fig.4a, DC drive system works in period-1 operation under normal condition. In period-1 operation, the DC drive system behaves limit cycle like Fig. 4a. When $V_{in}=40$, the system has chaotic behavior as seen in Fig. 4b. After controller based on time delay feedback control with $K=500$ and $\tau=10^{-5}$ is applied to the system which operates in chaotic operation, the system behavior is seen to change from chaotic operation to normal operation as shown in Fig. 4c.

V. Conclusion

This work addresses controlling ans stabilizing chaos which occurs in a current mode controlled DC chopper-fed PM DC drive system by using time delay feedbaack control technique. The controller designed based on the time delay feedback control theory is proposed to realize the stability of the controlled system. It is showed that the chaotic oscillations successfully suppressed by applying proposed control technique.

References

[1] S. Banerjee, G.C. Verghese, Nonlinear Phenomena in Power Electronics: Attractors, Bifurcations, Chaos, and Non-linear Control. IEEE Press, 2001

[2] S. Ürgün, T. Erfidan, N. Çoruh, DA-DA Buck Dönüştürücü Tasarımı ve Gerçeklenmesi, ELECO'2008 Elektrik - Elektronik - Bilgisayar Mühendisliği Sempozyumu ve Fuarı, 2008

[3] M.D. Bernardo, C.K.Tse, Chaos in Power Electronics: An Overview

[4] J.G. Kassakian, M.F. Schlecht, G.C. Verghese, Principles of Power Electronics, Addison--Wesley, 1991

[5] E. Ott, C. Grebogi, J.A. Yorke, Controlling chaos, Physical Review Letters, vol. 64, no. 11, pp. 1196-1199, 1990

[6] N. Zhu, W. Weilin, Two-Parameter Chaotic Control In The Voltage Controlled Buck Converter, The Fifth International Conference on Power Electronics and Drive Systems, 2003. PEDS 2003

[7] K. Pyragas, Continuous Control Of Chaos By Self-Controlling Feedback, Phys. Lett. A, Vol. 170, Pp.421 - 428 , 1992

[8] C. Batlle, E. Fossas, G. Olivar, Time-Delay Stabilization Of The Buck Converter, 1st International Conference Control of Oscillations and Chaos Proceedings, 1997

[9] J.H. Chen, K.T Chau, C.C. Chan, Chaos in voltage-mode controlled DC drive systems, INT. J. Electronics, vol. 86, no. 7, 857- 874, 1999

[10] J. H. Chen, K. T. Chau, and C. C. Chan, Analysis of chaos in current-mode-controlled DC drive systems, Industrial Electronics, IEEE Transactions on, Vol. 47, pp. 67-76, 2000

[11] B. Basak, S. Parui, Bifurcation and chaos in a phase controlled rectifier-fed dc drive under voltage mode control, 2010 Annual IEEE India Conference (INDICON), Kolkata, India, 2010

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