Command Filtered Control for PMSMs Discrete-Time System with Input Saturation

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Introduction

Input saturation is inevitable in the field of motor control. Excessive input voltage prevents the PMSMs from operating normally, and in severe cases it will burn the PMSMs. There will be a saturated nonlinear term in the motor control system, which will increase the complexity of the algorithm and reduce the stability of the system. It is worth noting that the above method is based on a continuous-time control system. Discrete-time systems are widely used in digital computers and are more suitable for practical applications. Compared with the continuous system, the discrete-time system has advantages in realizability and stability. Considering input saturation is still a hot topic of research in discrete-time systems of PMSMs.

The backstepping has a major breakthrough in solving nonlinear systems and is widely used in PMSMs systems. As the order of the system increases, the problem of "complexity of computation" arises in the backstepping method. It is worth considering that the command filtered control method not only solves the "complexity of computation" problem in the traditional backstepping method but also uses a compensation mechanism to eliminate filtering errors and improve the control accuracy of the system. In the simulation results, this paper uses Lyapunov function to prove the feasibility of the proposed control method. We can conclude that all closed-loop signals are semi-global uniformly ultimate bounded.

Mathematical Formulas

The mathematical model of the motor is expressed as

$$\begin{cases} x_1(k+1) = x_1(k) + \Delta_T x_2(k) \\ x_2(k+1) = a_1\Delta_T x_3(k) + (1+\Delta_T a_2)x_2(k) \\ \qquad +a_3\Delta_T x_3(k)x_4(k) + a_4\Delta_T T_l \\ x_3(k+1) = (1+b_1\Delta_T)x_3(k) + b_2\Delta_T x_2(k) \\ \qquad +b_3\Delta_T x_2(k)x_4(k) + b_4\Delta_T u_{qs}(k) \\ x_4(k+1) = (1+c_1\Delta_T)x_4(k) + c_2\Delta_T x_2(k)x_3(k) \\ \qquad +c_3\Delta_T u_{ds}(k) \end{cases} \tag{1}$$

The error signal and compensation signal of the system are defined as:

$$\begin{cases} e_1(k) = x_1(k) - x_{1d}(k) \\ e_2(k) = x_2(k) - x_{1c}(k) \\ e_3(k) = x_3(k) - x_{2c}(k) \\ e_4(k) = x_4(k) \end{cases} \begin{cases} \xi_1(k) = e_1(k) - \varsigma_1(k) \\ \xi_2(k) = e_2(k) - \varsigma_2(k) \\ \xi_3(k) = e_3(k) - \varsigma_3(k) \\ \xi_4(k) = e_4(k) - \varsigma_4(k) \end{cases} \tag{2}$$

With the command filtered adaptive fuzzy control method, the virtual control function is defined as

$$\alpha_1(k) = \frac{x_{1d}(k+1) - x_1(k)}{\Delta_T} + t_1\xi_1(k) \tag{3}$$

$$\alpha_2(k) = \frac{-(1+\Delta_T a_2)x_2(k) + x_{1c}(k+1)}{a_1\Delta_T} + t_2\xi_2(k) \tag{4}$$

The following error compensation signals are further defined

$$\xi_1(k+1) = \Delta_T(\xi_2(k) + x_{1c}(k) - \alpha_1(k) + t_1\xi_1(k)) \tag{5}$$

$$\xi_2(k+1) = a_1\Delta_T(\xi_3(k) + x_{2c}(k) - \alpha_2(k) + t_2\xi_2(k)) \tag{6}$$

Under the condition of input saturation, the saturated nonlinear input signal and the input signal of PMSMs drive systems are chosen as

$$\begin{cases} v_q(k) = -\dfrac{1}{b_4\Delta_T}\hat{\chi}_3(k)\|S_3(Z_3(k))\| \\ u_{qs}(k) = g_{v_\lambda(k)}v_q(k) + Y(v_q(k)) \end{cases} \tag{7}$$

$$\begin{cases} v_d(k) = -\dfrac{1}{c_3\Delta_T}\hat{\chi}_4(k)\|S_4(Z_4(k))\| \\ u_{ds}(k) = g_{v_\lambda(k)}v_d(k) + Y(v_d(k)) \end{cases} \tag{8}$$

Figures

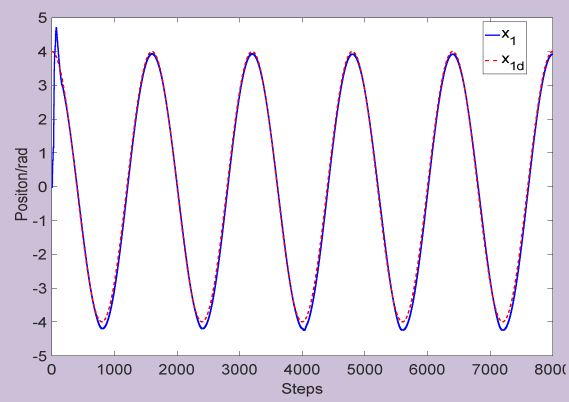

Figure 1. The trajectory of x_1 and x_{1d}

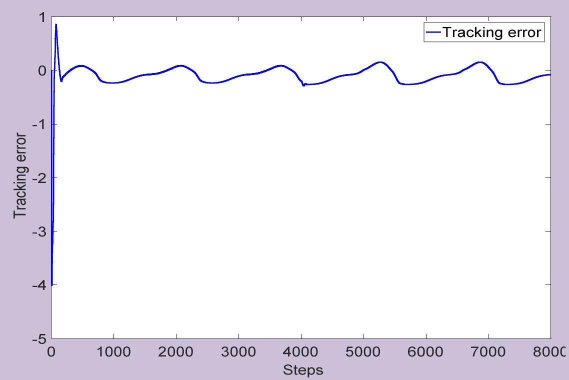

Figure 2. Tracking error ($x_1 - x_{1d}$)

Conclusion

Figure 1 shows the rotor angular position x_1 curve and the reference signal x_{1d} curve of the command-filtered PMSMs for input saturation. It can be seen from the simulation diagram that the rotor angular position curve can track the reference signal well. Figure 2 shows the error curve of the rotor angular position and the reference signal under the influence of input saturation. The command filtered control method proposed in this paper has better position tracking performance and smaller tracking error.