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SLIDING MODE CONTROL WITH PROPORTIONAL-INTEGRAL COMPENSATION AND APPLICATION TO AN INVERTED PENDULUM SYSTEM

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Abstract. *This paper proposes a new method for designing a variable structure controller in the presence of load disturbance or plant parameter variation. In conventional methods, servo tracking is achieved by a variable structure controller designed using integral compensation. However, the proposed method employs proportional compensation as well as integral compensation, and optimal proportional and integral gain for stabilizing a closed-loop system can be obtained by solving the Riccati equation. As a result, robust servo tracking can be achieved and further, transient response is better than that of conventional methods. The proposed method is applied to an inverted pendulum system, and its effectiveness is demonstrated by both simulation and experiment.*
Keywords: Variable structure control, Sliding mode, Inverted pendulum, Nonlinear system, Proportional-integral compensation, Phase property

1. **Introduction.** Variable structure control [1, 2, 3] can be easily applied to nonlinear systems and is robust to plant parameter variation or load disturbance because of the existence of a sliding mode. Furthermore, design methods employing integral compensation have been proposed to achieve servo tracking in the presence of load disturbance or plant parameter variation [4, 5, 6]. Robust tracking servo can be attained with a controller using integral compensation but the integral action causes phase lag, which deteriorates control performance. However, proportional compensation can adjust the gain property without changing the phase property. Hence, if control systems are designed to use proportional compensation as well as integral compensation, control performance can be further improved. Therefore, this paper proposes a method for designing a sliding mode controller using both proportional and integral compensations. Hence, the proposed method has higher potential than conventional methods [4, 5, 6]. In the proposed method, robust servo tracking in steady state is achieved by using integral compensation, and transient response is enhanced by using proportional compensation. Hence, both responses are improved. In conventional methods, to determine the switching plane and the integral gain, a quadratic function is minimized by using the optimal linear regulator technique [4] or the characteristics equation of a closed-loop system is assigned to have desired eigenvalues [5, 6]. The proposed method employs the optimal linear regulator technique to determine an optimal switching plane, proportional gain and integral gain to stabilize a closed-loop system.

To demonstrate the potential of the proposed method, the designed variable structure controller is applied to an inverted pendulum system that has been developed to study bifurcations and chaos [8, 9, 10]. Because of the existence of unknown disturbances and