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Fractional Order Complementary Non-singular Terminal Sliding Mode Control of PMSM Based on Neural Network

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Abstract
Aiming at the sensitivity problems of uncertain factors such as parameter variation, external disturbance and friction for the permanent magnet synchronous motor control system of electric vehicle, a fractional order complementary non-singular terminal sliding mode control method based on neural network is proposed. The mathematical model of permanent magnet synchronous motor with uncertain factors was established. The sliding mode controller was designed by combining the generalized sliding mode surface and the complementary sliding mode surface, which shortened the arrival time from the state trajectory to sliding mode surface. The fractional calculus operator with filtering characteristics was used to improve the position tracking accuracy and reduce the chattering. As for the variety of uncertain disturbances, the neural network was used to estimate the system total uncertainty and compensate online to further improve the dynamic response ability and anti-interference ability. Finally, the simulation results verify the effectiveness and feasibility of the proposed method, which can provide theoretical and technical support for improving the control accuracy of permanent magnet synchronous motor and the development of electric vehicles.

Keywords Permanent magnet synchronous motor · Fractional order complementary · Neural network · Electric vehicle drive system · Non-singular terminal sliding mode

1 Introduction

Permanent magnet synchronous motor (PMSM) is widely used in the field of electric vehicle drive system because of its simple structure, high power density, high reliability and small space occupation. However, PMSM is a nonlinear, multivariable and strongly coupled system, which makes it difficult to improve its dynamic and static performance due to the external disturbances, parameter disturbances and other effects (Cai et al., 2017). In recent years, some relevant scholars have proposed a variety of control strategies to suppress the uncertain interference of the system and improve the related performance of the control system; such as sliding mode control (Li et al., 2023), active disturbance rejection control (Cao et al., 2023; Xu et al., 2023; Xu et al., 2023), neural network control (Li et al., 2022; Lu et al., 2015; Yu et al., 2015), model predictive (Bai et al., 2022; Zhang et al., 2021), etc.

Sliding mode control (SMC) is widely used because of its strong robustness and insensitivity to external reactions (Wang, 2020). However, there are problems of control discontinuity and chattering, so in most cases, other control methods need to be combined to achieve better control effect. In Li et al., (2021), a back-stepping non-singular terminal sliding mode control method with finite time disturbance observer is proposed, where the load torque disturbance is assumed to change slowly and the load is bounded. In Du et al., (2022), the super-twisting sliding mode algorithm is introduced into the active disturbance rejection control by combining active disturbance rejection control and sliding mode control, and the nonlinear state error feedback control rate and tracking differentiator are optimized to improve the fast performance of the system. Li et al., (2021) designed a fractional order sliding mode surface for permanent magnet synchronous motor speed control system, through the fractional order calculus operator unique memory characteristics

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