Super Twisting Sliding Mode Control with Accelerated Gradient Descent Method for Synchronous Reluctance Motor Control System

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Abstract. We propose the new speed and optimal current vector control schemes for synchronous reluctance motors (SynRMs) to achieve fast dynamic response and high efficiency using the super-twisting sliding mode control (STSMC) algorithm and the accelerated gradient descent method (AGDM). Through the experimental testing using the 500W SynRM control system, the proposed STSMC-AGDM scheme shows the better speed control performance and motor efficiency, compared with the conventional proportional-integrator (PI) control with/without AGDM, and STSMC without AGDM.

Introduction

Synchronous reluctance motors (SynRMs) have received a considerable attention in various engineering applications due to its high efficiency, low cost, and fault-tolerant capabilities, compared to other types of motors such as induction motors and PMSMs [1]. The general SynRM control system (see Figure 1) requires the design of speed controller, current vector control algorithm, and current controller. Specifically, the magnitude of current is obtained from the speed controller. Subsequently, the current phase angle is determined by the current vector control algorithm. Based on the magnitude and phase angle of current, the command of dq-axis current is computed. Thereafter, the dq-axis voltage command is obtained using the current controller. The three-phase voltage is applied to SynRM using the voltage source inverter by space vector pulse width modulation. We propose the new speed and optimal current vector control schemes for SynRMs for fast dynamic response and high efficiency using the super-twisting sliding mode control (STSMC) algorithm and the accelerated gradient descent method (AGDM). In current control, PI and first-order SMC are widely used. However, a satisfactory control performance may not be guaranteed due to the presence of nonlinearities, chattering by discontinuity of SMC, and disturbances. To resolve these issues, we propose STSMC, which is continuous and achieves a fast dynamic response under disturbances. For current vector control, there are various approaches such as MTPA, FW, MTPV, MPFC, and MEC, which however may not be reliable when the motor parameters have high nonlinear characteristics due to the magnetic saturation [2]. The approach of using Lookup Tables (LUTs) based on FEA has been used widely to cope with such nonlinearities [3]. We apply the AGDM to improve searching the optimal current vector in LUTs. The proposed STSMC-AGDM is implemented in the 500W SynRM system (see Figure 1), where the experiment results show the better speed control performance and motor efficiency, compared with the conventional PI control with/without AGDM, and STSMC without AGDM.

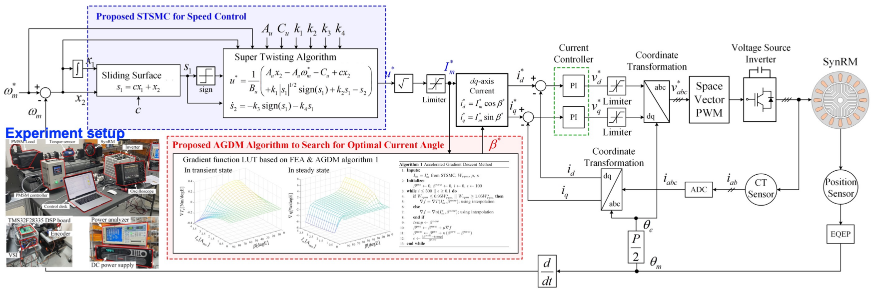

Table 1. Performance comparison of four control schemes

Content	PISC-TMTPA	STSMC-TMTPA	PISC-AGDM	**Proposed STSMC-AGDM**
Response time of Cases 1-1 and 2-1	2.6[sec]	0.84[sec]	2.56[sec]	**0.8[sec]**
Response time of Cases 1-2 and 2-2	2.66[sec]	0.88[sec]	2.32[sec]	**0.8[sec]**
Response time of Cases 3	2.1[sec]	0.8[sec]	2.1[sec]	**0.5[sec]**
Efficiency @ 1[Nm], 1000[r/min]	78.97[%]	78.97[%]	79.3[%]	**79.27[%]**
Efficiency @ 3[Nm], 1000[r/min]	81.29[%]	81.29[%]	81.52[%]	**81.54[%]**
Efficiency @ 1[Nm], 1200[r/min]	80.21[%]	80.22[%]	80.56[%]	**80.57[%]**
Efficiency @ 3[Nm], 1200[r/min]	82.24 [%]	82.24 [%]	82.38 [%]	**82.39 [%]**
Efficiency @ 3[Nm], 1500[r/min]	85.53 [%]	85.54 [%]	85.8 [%]	**85.82 [%]**

Figure 1: Block diagram, experiment setup, and experiment result of the proposed STSMC-AGDM based SynRM Control System.

Results and Discussion

Figure 1 shows the proposed STSMC-AGDM based SynRM control system, where STSMC is used for speed control and AGDM is applied to optimal current vector control in LUTs. The other blocks in Figure 1, including dq-axis current, PI current controller, limiters, coordinate transformation, ADCs, voltage source inverter, and sensors, are also implmented. The main features of the proposed STSMC-AGDM are as follows: (i) STSMC provides a faster finite-time reachability than the conventional first-order SMC and (ii) AGDM allows to quickly search for the optimal current vector in LUTs to deal with nonlinear motor characteristics.

References

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