Instantaneous torque control is directly based on sliding mode control of SRM

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Abstract: Since the sliding mode control (SMC) of the sliding mode can be designed, and is independent of parameter variations and disturbances outside of the control target, the sliding mode control has the advantages of fast response, insensitive to the parameter change and external disturbance, and is easy to realize other control systems. It is an effective way to solve nonlinear problems. Characteristics inherent nonlinearity and strong coupling of the switched reluctance motor (SRM) itself, based on the traditional text directly on the instantaneous torque control, the torque distribution function provides a real-time compensation scheme. In Matlab/Simulink environment, the simulation results show that the improved control strategies can reduce torque ripple of SRM, increase the robustness of the system.

1. Introduction

Reaction with the same stepping motor, switched reluctance motor is a doubly salient variable reluctance motors, which are merely laminated rotor made of silicon, which is neither the windings nor permanent magnets on the rotor, the stator is concentrated winding. Therefore SRM structure is simple, low cost, high efficiency, and good robustness, which makes it widely used in power transmission field. However, due to its inherent stator and rotor structure, the steady-state torque SRM has great volatility, which limits the application of SRM.[1][2]

Generally, the torque ripple can be reduced SRM divided into two ways, one is to optimize the structure parameters of the motor body. The other is the use of advanced control strategies, better tracking a given torque. SRM control strategy is divided into two: one is indirect torque control, the torque output of this method is the speed loop setpoint by a torque sharing function (TSF) reasonably assigned to each phase, and then obtained by the torque per phase inverse model reference current, closed-loop control and the actual current; the other is likewise given to the torque distribution through the TSF each phase, and each phase current and the rotor position angle estimate the actual revolution speed moment, so as to realize closed loop control of the torque.[3][4]

In the traditional DTC, the modern control algorithm is combined with the advanced control algorithm. The terminal sliding mode control adopts the outer loop closed-loop speed controller. In the traditional DTC inner loop control, the real-time compensation scheme is realized by using the genetic torque distribution control function. In Matlab/Simulink, the improved control strategy is verified.

2. SRM torque distribution function Control Strategy

The control block diagram of the SRM torque distribution function uses a double closed-loop structure. The outer ring is a speed loop. The system reference torque is obtained through sliding mode variable structure control adjustment. The inner ring is a torque loop., The torque error of each phase, the rotor
position signal is converted into the control signal of the power converter through torque hysteresis control, and the SRM control is realized.[5][6].

In TSF control, there will be large torque fluctuations during commutation. On the one hand, at the beginning of the commutation phase, the latter phase is near the misaligned position of the stator and rotor of the motor. The rate of change of the inductance increase of this phase is relatively low. At this time, the phase's ability to generate torque is weak and it is difficult to track the feed Constant torque, which will cause the total combined torque of the motor to be low; on the other hand, at the end of commutation, the position where the previous phase generates torque is near the motor's fixed rotor alignment position, and the inductance of this phase at this position The rate of change of the rise is large, so that the torque of this phase cannot be reduced quickly, so it cannot be reduced to a given torque quickly. This causes the total combined torque of the motor to be high, which causes the motor to pulsate.[7][8].

2.1 compensation torque distribution control function Online

Because of these problems the switched reluctance motor, the paper proposes a TSF online compensation control strategy, this method can solve the above two problems, reduce torque ripple during commutation SRM generated, such that commutation process is more stable, which control block diagram shown in Fig 1.

As shown in Fig 1, the TSF online compensation control is based on the traditional TSF, by adding a compensator to perform online compensation of the reference torque, so that the reference torque is more reasonably distributed through the new TSF, which in turn makes the combined torque more stable.

In order to make the TSF online compensation more targeted, the commutation of the motor is divided into three parts, namely section I, section II and section III. The separation point of interval I and interval II is the moment when the reference torque of the latter phase is equal to its actual torque; the separation point of interval II and interval III is the moment when the reference torque of the previous phase is less than its actual torque. The comparison between the TSF online compensation control proposed in this paper and the traditional preset TSF control is shown in Fig 2, where the dotted line is the online compensation TSF and the solid line is the traditional preset TSF.
According to the running state of the motor during the commutation period, torque compensation is performed for the sections I, II, and III, respectively. In section I, the actual torque of the latter phase of the motor cannot track its reference torque, resulting in a lower combined torque. At this time, the previous phase can be compared with Good tracking of its reference torque, so that the torque of the next phase can be compensated by raising the reference torque of the previous phase.

In section I, first find the error between the reference torque of the next phase and its actual torque, and then divide the torque error of the subsequent phase by the total reference torque to get the online compensation value of the previous phase TSF. Adding the preset value of the previous phase is the torque distribution function of the new previous phase, and the TSF of the latter phase remains unchanged. The calculation formulas are shown in equations (1) to (5), respectively.

\[
\Delta T_1 = T_{ref}(k+1) - T(k+1) \\
\Delta f_1 = \frac{\Delta T_1}{T_{ref}} \\
f_{k+1}^{new}(\theta) = f_k(\theta) + \Delta f_1 \\
T_{ref}^{new}(k) = T_{ref} f_{k+1}^{new}(\theta) \\
T_{ref}^{new}(k+1) = T_{ref} f_{k+1}(\theta)
\]

In the interval II, the previous phase and the latter phase can track the given torque better, so its TSF remains unchanged, and its expressions are shown by equations (6) and (7).

\[
T_{ref}^{new}(k) = T_{ref} f_k(\theta) \\
T_{ref}^{new}(k+1) = T_{ref} f_{k+1}(\theta)
\]

In section III, the torque of the previous phase cannot track its given torque well, that is, the torque of the previous phase cannot quickly drop to its reference torque, so the actual torque of the previous phase and its reference revolution There is a certain error between the moments, which makes the actual combined torque of the motor higher. At this time, the torque of the latter phase can already track its given torque well. Therefore, the TSF of the latter phase can be reduced to correct the torque of the former phase.

In section III, first find the error between the reference torque of the previous phase and its actual torque, and then divide this torque error by the total reference torque to get the online correction value of the TSF of the next phase. Its expression This is shown in equation (8). The equations (9) and (10) can be used to obtain the TSF and reference torque after the latter phase compensation, respectively. The TSF and phase reference torque of the previous phase remain unchanged, and the expression is shown in equation (11)

\[
\Delta f_{III}(\theta) = \frac{\Delta T_{III}}{T_{ref}} = \frac{T_{ref}(k) - T(k)}{T_{ref}} \\
f_{k+1}^{new}(\theta) = f_{k+1}(\theta) + \Delta f_{III} \\
T_{ref}^{new}(k+1) = T_{ref} f_{k+1}^{new}(\theta) \\
T_{ref}^{new}(k) = T_{ref} f_k(\theta)
\]

After online compensation of the torque distribution functions in these three sections, the total reference torque of the motor is more reasonably distributed according to its operating characteristics, so that the torque ripple of the switched reluctance motor is better. The new reference torque of each phase after online compensation is shown in Fig3.
3. Simulation and Analysis

In order to verify the validity of the proposed scheme, to a 3KW, 12/8 pole three-phase SRM as the control object, to verify the model built in Matlab/Simulink environment. The look-up table based on the torque data obtained in the simulation model using asymmetrical half-bridge power converter circuit, the phase value of the torque.

Fig. 3 Reference torque after TSF online compensation

Fig. 4 is a torque waveform diagram of the SRM, the speed of 300r/min, the load torque of 5N/m. As can be seen from the figure, in the interval I, after a phase lag behind changes in the torque phase reference value thereof, resulting in a torque recess; III in section, a front torque phase is reduced to not timely its reference value, resulting in total torque convex liter, By combining Fig. 4 with formula (8), it can be obtained that, torque ripple in this case 7.6%.

Fig. 4 Torque profile of traditional TSF control

Fig 5 is a composite torque waveform diagram of direct instantaneous torque control based on sliding mode control at a motor speed of 300 r/min and a load of 5 N/m. It can be seen from the figure that the torque ripple of the improved system is more It is small, and the torque ripple rate of the motor can be reduced to 1.9% through equation (8).

Fig. 5 Torque profile after improved

Set the speed to 300r/min, the initial load torque is 5N/m, and the load torque suddenly increases to 7.5 N/m at 0.3s. The torque waveform diagram of the traditional TSF control and improved control methodAs shown in Fig 6 and Fig 7, respectively.

FIG 6 a conventional control TSF sudden load torque waveform
Comparing Fig (6) and Fig (7), it can be seen that the torque ripple of the improved control method is smaller. When the load changes, its response is faster, the overshoot is smaller, and the ability to resist interference is stronger.

5 Conclusion
In this paper, the instantaneous torque direct control strategy of SRM is analyzed, and the causes of torque ripple during SRM commutation are mainly analyzed. A targeted online compensation scheme of torque distribution function is proposed to better restrain the torque ripple during SRM commutation. In order to improve the robustness of the system, the sliding mode terminal of the speed controller is designed. The simulation results show that the control strategy proposed in this paper can reduce the torque ripple of SRM at low speed commutation, reduce the difference of load torque, and has the characteristics of fast response speed, small overshoot and strong anti-interference ability.

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