Permanent magnet brushless dc motor device analysis and manage: Based on the electric motor simulation

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Abstract

We have analyzed the permanent magnet brushless dc motor and simulated the process that motor parameters affect pulsating torque and average torque, which were compared with permanent magnet synchronous motor.We concluded that permanent magnet brushless dc motor has the asset in high torque density and low inverse capacity, which makes its driving performance better than permanent magnet synchronous motor.

Keywords

Permanent magnet brushless dc motor, permanent magnet synchronous motor, parameters, simulation.

1. Introduction

At present, the energy crisis and environmental pollution are becoming more prominent outstanding eventually, which has aroused huge concern for the development of efficient, energy-saving and environmental-friendly electric vehicles. Performance index of electric vehicle largely depends on the property of its motor speed determine system.Therefore, the selecting of a motor speed control system with excellent performance becomes the significant decision in electric vehicle design.The permanent magnet brushless dc motor does not construct a traditional dc motor that has a mechanical phase change structure. But it has superiorities in stable structure, wide speed scale, low speed performance, high power density and easy maintenance etc. All these make it suitable to use as the driving motor for an electric car.

2. Analysis of permanent magnet brushless dc motor

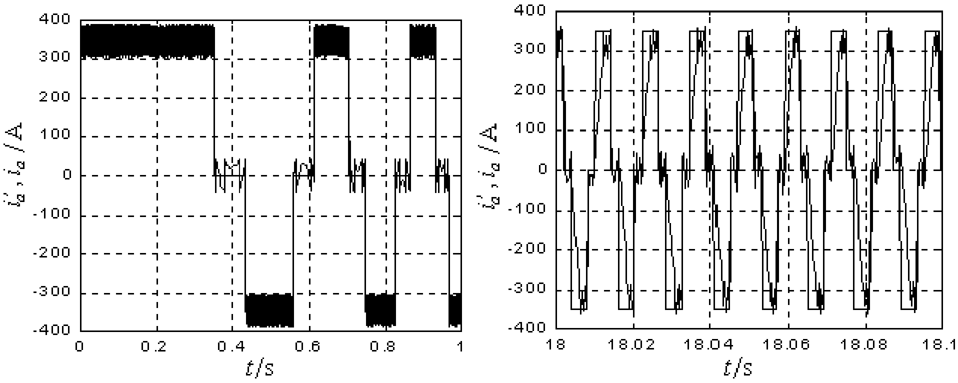
2.1 General analysis

The ideal operational requirement for Permanent magnet brushless dc motor is a trapezoidal potential waveform whose flat wave width is greater than 120 ° and a continuous 120 ° square wave current waveform.In general, that demand for potential waves is a manageable problem.It is easy to satisfy the potential waves. But there has a conundrum in how to mediate an utter tracking of motor current for a given current, especially for electric vehicle drive, with large load of torque and moment of inertia.For the permanent magnet brushless dc motor with current closed-loop control, motor current tracking includes commutation current tracking and hysteresis loop comparison tracking (as known as current hysteresis comparison tracking) in the current continuous phase. Apparently, that the permanent magnet brushless dc motor has both of positive commutating current tracking and suitable hysteresis comparison tracking ,which would impel motor to provide expected given torque with small torque ripple.

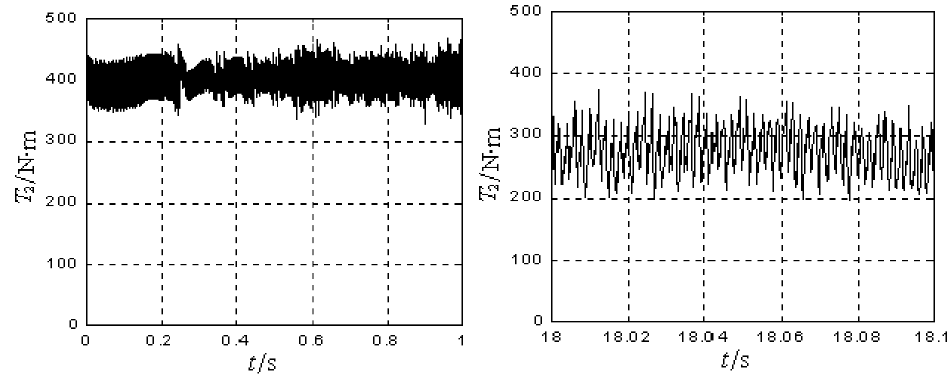
Whether current hysteresis comparison tracking, or commutation tracking are both determined by the motor time constant (the ratio of motor winding leakage inductance and resistance),or the difference between its counter potential and the dc side voltage.Figure 1 shows the different current tracking performance and the resulting torque performance of the motor at different speed segments (hence different potential voltage differences).It can be perceived that the difference between potential and voltage has an important effect on current tracking performance and its torque in a motor within same time constant.At low speed, the motor does a good current tracking performance, which reconciles it into a expected average torque, and the torque ripple caused by current reversal is slight, but the good tracking of current makes the motor’s hysteresis overshoot, resulting in the torque ripple caused by current hysteresis; In high speed, on the other hand, the current tracking performance reduces, It reduces current hysteresis comparison of torque ripple.But, because of weaker of current commutation tracking, current hysteresis is increased by current commutation.Thus, the current tracking capacity have different effect on the motor. when it is running at speed, the motor has different requirements on its current tracking performance. At high speed, the motor is expected to improve the tracking capacity to generate the expected average torque, while at a low one , the current tracking capacity is weakened to reduce the torque ripple.

2.2 Comparative analysis with permanent magnet synchronous motor

Compared with permanent magnet synchronous motor, the brushless dc motor's current traceability is worse, which makes its superiorities greater than permanent magnet synchronous motor torque density and smaller inverter capacity under a largely abate.



(a) The current simulation waveforms



(b)Torque simulation waveforms

Figure 1 simulation waveforms of current and torque at different speeds

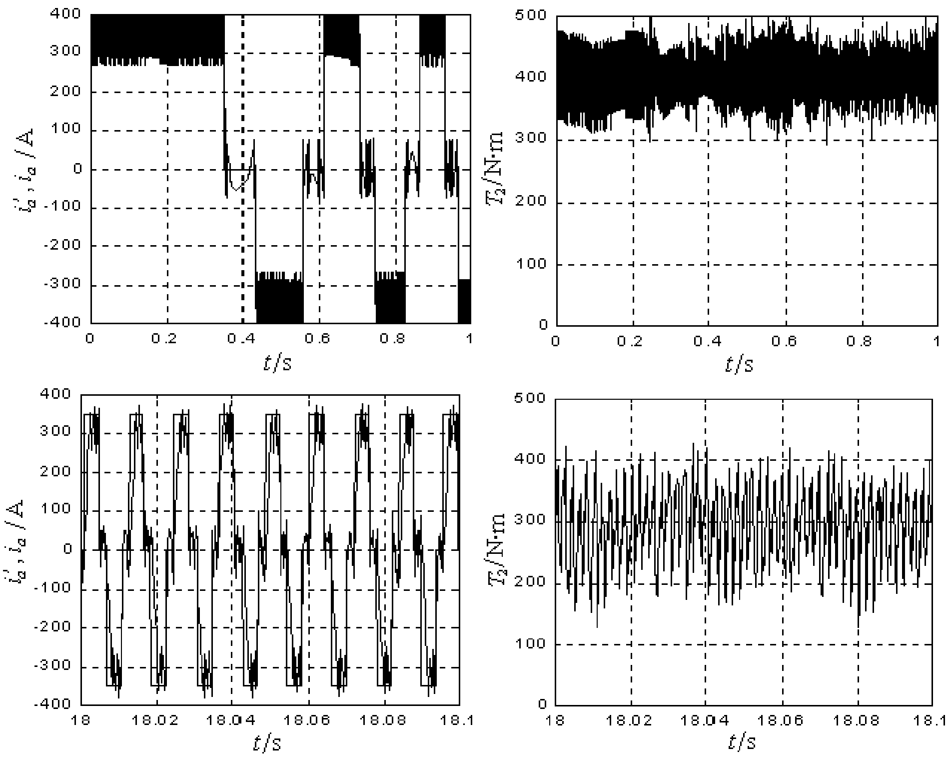
3. Influence of motor parameters on ripple torque and average torque

3.1 Analysis of low speed torque ripple and high speed torque ripple

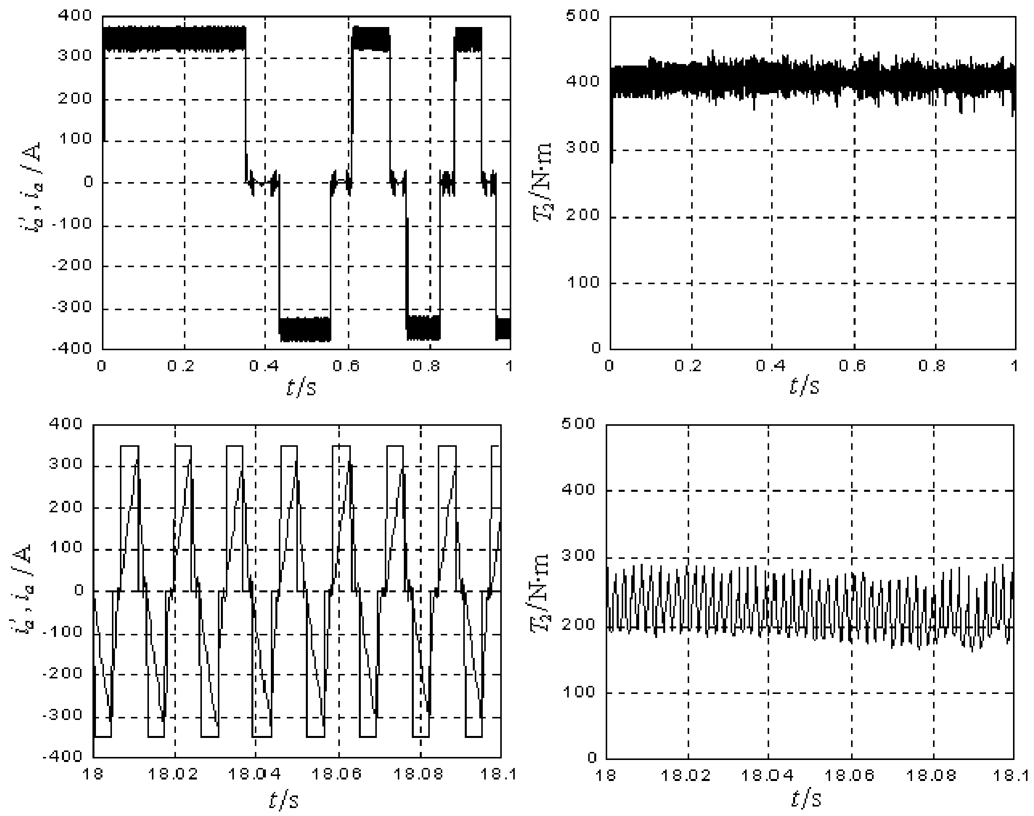
At high speed, the torque ripple of the motor is important. What is consequential is that the motor are required to have a high-speed average torque which would not reduce too much and a short low-speed torque ripple, that induces the paradox between low-speed and high-speed motor current tracking.That is, the required traceability of current is terrible at low speed, which could make its current does not excessively overshoot to the given current, causing a overlarge torque ripple at low speed;At high speed, it is necessary to have a good current tracking performance, so that the motor current can be quickly commutated, which would not be reduced by slow current commutation.As the speed increases, the motor potential will gradually approach the dc voltage of motor, which is an inevitable limitation, it could only be alleviated by choosing a legitimate motor's time constant.

3.2 Simulation analysis of leakage inductance change

It is necessarily required to reduce the resistance as for as possible.The leakage inductance of motor is determined by time constant.In figure 2,(a) is a simulation curve of torque and current (given and actual current) changing by time when a motor of a electric vehicle is operating.At this moment, its resistance is 0.02897Ω and the leakage inductance is 0.00018H (in figure 2a and 2b, it is expressed in diagrams that the changing by time in a simulation curve of torque and current (given and actual current when a motor of an electric vehicle is operating). At the same time, the leakage inductance of curve (b) is 0.0006H,Other with (a).Figure 3(Figure 3 with other conditions remaining same) shows the simulation curve of their rotational speed potential, where half of the motor's dc side voltage is about 110V.When the small leakage inductance of motor is compared with large leakage inductance, the former has a smaller time constant, and its current hysteresis comparison overshoot.It also has a larger electric current pulse leading to large torque ripple at low speed, but this basically does not affect the average-torque, on the contrary, at high speed due to good commutating current tracking the former has greater high-speed average torque. It can be obviously perceived in figure 3a showing the speed changing curve.

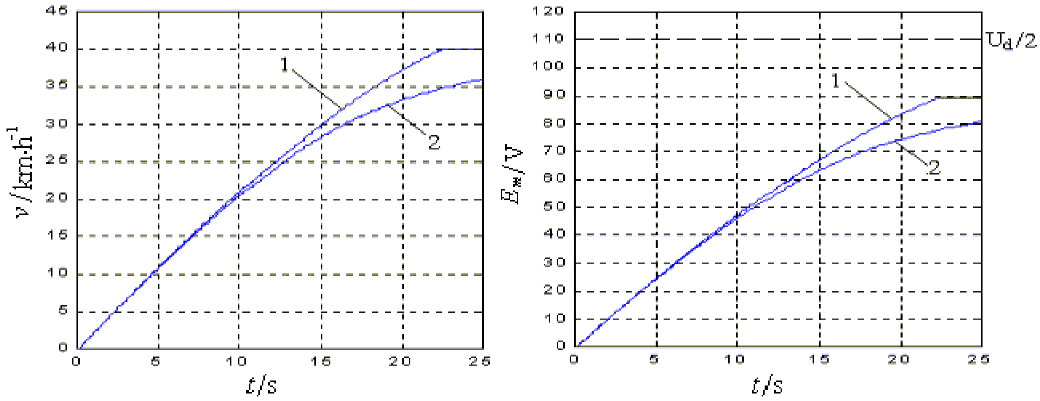


(a) The leakage sense is 0.00018



(b) The leakage sense is 0.0006

FIG. 2 Simulation of electromagnetic torque current variation curve of motor with different leakage inductance



(a) Simulation curve of rotational speed change (b) Simulation curve of potential change

1 — Lσ = 0.00018 2 —Lσ = 0.0006

Figure 3 Simulation curve of phase potential change of motor speed at different leakage inductance

4. Conclusion

The foregoing analysis shows that the permanent magnet brushless dc motor is driven by an electric vehicle at low speed, it is expected to have a larger sense of leakage. So as to obtain a set of current and torque pulsation caused by a smaller current hysteresis comparison; At high speed, small leakage inductance is expected to make the motor have good current commutation tracking, so as to reduce the average torque reduction. In other words, the requirement of permanent magnet brushless dc motor driven by electric vehicles between low speed and high speed is contradictory. By using the method of serial reactor can effectively solve the problem. It should have a smaller leakage inductance When we designs a motor, when a motor is designed. At low speed, it is connected with a reactor in series, which would be removed at high speed.

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