Research on Energy Efficiency System of New Energy Vehicle Electric Drive

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Abstract. The motors of new energy vehicles adopt the built-in permanent magnet synchronous motor (PMSM) with high system efficiency. The mainstream control method of electric drive system is space vector PWM (SVPWM) algorithm. The SVPWM algorithm has higher low-order harmonic content in the low-speed segment voltage waveform, large asynchronous motor torque, and large motor iron loss, which makes the electric drive system less efficient in the low-speed segment system. This paper creatively proposes to change the modulation ratio M of the SVPWM waveform by adjusting the bus voltage, switching frequency and different control angles to reduce the harmonic content of the system to improve the overall efficiency of the electric drive system. In this paper, a theoretical model is established for the motor phase voltage harmonics, and various factors and components affecting the harmonic content are analyzed. Combined with the digital signal processor (DSP) based SVPWM vector control algorithm, the motor control SIMULINK simulation system is built. The voltage harmonic analysis of the simulation system is carried out by using the FFT tool in POWERGUI. The electric drive system bench is established for testing, the electric drive system simulation and the test bench test data are analyzed, and a clear method and means are proposed to reduce the harmonic content.

1. Introduction
With the development of China’s economy, the problem of air pollution is becoming more and more serious. Among them, automobile exhaust is a major source of pollution in cities. In addition, the rapid development of China’s economy has also forced China’s oil import dependence to be greater than 60%. Driven by the two main factors of energy conservation, environmental protection and energy security, China’s new energy automobile industry has been vigorously promoted as a new key industry during the 13th Five-Year Plan period. At the same time, the “13th Five-Year Development Plan for Strategic Emerging Industries in Anhui Province” also clearly defined 10 major areas such as the development of new displays, robots, new energy vehicles, modern Chinese medicine, and biomedicine. Among them, the electric vehicles in the new energy vehicles will be the key development areas, and can solve the problem of urban air pollution.

The main drive of new energy vehicles adopts PMSM. The overall efficiency of this kind of motor is high. No matter the area of highest efficiency or high efficiency, it is much higher than asynchronous motor and switched reluctance motor. It has become the mainstream technical solution for new energy vehicles at home and abroad [1, 2]. At present, the technical level of domestic drive motor parts is close to the international level, but there is still a big gap between the level of high
efficiency and energy saving and the international level, mainly in terms of system efficiency, safety and reliability [3, 4, 5]. For example, Japan Nissan pure electric vehicle “Learning Wind”, through competitive bidding analysis, the efficiency of the area greater than 80% of the efficient area is greater than 76% of the entire working area, while the domestic motor enterprise product efficient area is less than 70%. The size of the high-efficiency area directly affects the driving range of the vehicle under the comprehensive road conditions, affecting the energy-saving effect and use cost of the new energy vehicle [6, 7].

In order to reduce the three-phase voltage harmonic problem of the frequency conversion debugging motor, technically solve the problem from two aspects of the motor body and the controller hardware topology, for example, the three-level IGBT module can reduce the three-phase voltage harmonic content, but increases The difficulty of control and the cost of hardware. This paper chooses the two-level IGBT module based on the existing large-scale use, and optimizes the design of the motor control system to reduce the phase voltage harmonic content.

2. Research methods

The use and popularity of electric vehicles depends to a large extent on the cruising range, the number and location of charging piles. How to improve the efficiency of electric vehicle electric drive system and increase the cruising range of the whole vehicle under comprehensive road conditions is related to the energy-saving effect and use cost of new energy vehicles. At present, there are many research results on energy efficiency control of new energy vehicles, but mainly focus on the two aspects of battery charging and discharging, and rarely consider the influence of factors such as battery bus voltage and motor asynchronous torque on the efficiency of electric drive system. At present, the motors of the new energy automobile city adopt the built-in permanent magnet synchronous motor (PMSM) with high system efficiency. The mainstream control method of the electric drive system is the space vector pulse width modulation (SVPWM) algorithm [8, 9].

Through practice and theoretical analysis, it is found that the efficiency of the electric drive system in the low speed section system is low, which is related to the lower harmonic content of the SVPWM voltage waveform in the low speed section, the large asynchronous torque of the motor, and the large iron loss of the motor. The creative proposal in this paper proposes to change the modulation ratio M of the SVPWM waveform by adjusting the bus voltage, switching frequency and different control angles to reduce the harmonic content of the system to improve the overall efficiency of the electric drive system.

In terms of research content, firstly, a theoretical model is established for the motor phase voltage harmonics, and various factors and components affecting the harmonic content are analyzed. Secondly, based on the basic theoretical analysis, combined with the digital signal processor (DSP) based SVPWM vector control algorithm, the motor control SIMULINK simulation system is built, and the voltage harmonic analysis of the simulation system is carried out by using the FFT tool in POWERGUI. To find out the engineering reasons and the influencing factors of the low efficiency of the electric drive system in the low-speed section of the new energy vehicle. Third, the establishment of the test conditions for the electric drive system bench leads to the bench test of the engineering factors and the influencing factors of the system inefficiency, and the actual engineering data is obtained. Fourthly, the data of simulation and experimental bench test of electric drive system are summarized and summarized. Based on the basic theoretical research of system voltage harmonics, the key factors and influence factors of system efficiency reduction are analyzed, and the proportion of high-efficiency area of the system is improved [10, 11].

By studying the low efficiency of the new energy vehicle electric drive system in the low speed section system, the area of the high efficiency area is increased, and the power consumption and the use cost of the whole vehicle are reduced. Through theoretical and practical data analysis, find out the related factors that affect the low efficiency of the low-speed segment of the electric drive system, such as SVPWM waveform harmonic content, bus voltage, modulation factor M, field weakening control angle, switching frequency and so on. Then through theoretical analysis, the mathematical
model of the above factors affecting the efficiency of the electric drive system is established, and the best solution is found through the analysis of the model. The technical principles are based on DSP-based SVPWM control algorithm, new energy vehicle PMSM electric drive system architecture and operation structure, SIMULINK virtual modeling technology, FFT digital signal processing analysis method and test bench test method.

The in-line “V”-shaped PMSM is studied to improve its efficiency in the low-speed segment. The method is to analyze the harmonic components in the low-speed SVPWM voltage and to identify the key factors affecting the total harmonics. Through the analysis of experimental data, the actual influence of various factors on the motor efficiency is obtained, which provides a more comprehensive reference for the later optimization design of the motor.

The research work is carried out through theoretical analysis, simulation and bench test, experimental data summary and feedback to improve the theoretical data model. The motor of the new energy vehicle electric drive system studied is an embedded “V” type PMSM, which is simulated and designed by Ansoft electromagnetic field finite element analysis software. The controller adopts a high-voltage IGBT (Insulated Gate Bipolar Transistor) based on DSP control, and a full-bridge hardware topology of the insulated gate bipolar transistor. The harmonic analysis design uses the MATLAB/SIMULINK software module. The test system uses an electric dynamometer system based on a power closed-loop structure, and the power analyzer uses a Japanese Yokogawa WT1800 motor test dedicated power analyzer.

![Figure 1. Schematic diagram of the structure of the electric dynamometer system](image)

The relevant bench experiment is carried out in combination with the specific products of the enterprise, and the power closed-loop experimental test system, that is, the electric dynamometer system, is constructed. The structure diagram is shown in Figure 1. The motor to be tested and the test motor are tested by the DC common bus scheme, and are composed of a torque sensor, a current sensor, a rotational speed sensor, a voltage differential probe, a power analyzer, and a constant temperature cooling circulating water system.

The theory of SVPWM voltage harmonic problem already exists, and the fundamental wave and each harmonic content can be accurately decomposed by Fourier transform. Therefore, there is not much difficulty in theoretical and technical methods. At the same time, based on DSP, the SVPWM vector motor controller performs orthogonal test on the dynamometer of the electric dynamometer by changing the test conditions such as bus voltage, modulation factor M, field weakening control angle and switching frequency, and accumulates test data and analyzes it. The key factors of the efficiency reduction of the electric drive system and its influence components are clarified, and a practical and feasible optimization method for improving the efficiency of the electric drive system is proposed to provide reference for engineering application.
3. Test plan
The mathematical model of the electric drive system SVPWM built in the MATLAB/SIMULINK environment, as shown in Figure 2, can be based on the SVPWM voltage harmonic theory simulation study to explore the influence of system parameters on the harmonic content under low speed conditions, as shown in Figure 3 and Figure 4, clear key factors, proposed and simulated verification engineering application improvement program.

Figure 2. SVPWM mathematical model

Figure 3. SVPWM voltage waveform
4. Conclusion
Due to the special working conditions of the car, the new energy vehicle drive motor has a wide working range, from low speed and small torque to high speed and high torque. It covers the whole process. From the perspective of high efficiency and energy consumption and vehicle use cost, it also needs to improve the efficiency of the whole working condition of the motor. Firstly, through the experimental test and analysis, it is found that the low speed section is less efficient, and the efficiency of the high speed weak magnetic section is about 30% lower. Considering the frequent starting of the whole vehicle and the low speed driving conditions in the urban area, it is of great significance to improve the efficiency of the low speed section electric drive system. Secondly, through the practice data accumulation analysis, the research and analysis of the harmonics of the SVPWM voltage waveform are proposed, and the reasons for the low efficiency of the low-speed motor system are explored, and detailed and feasible research ideas are drawn up. Finally, through theoretical analysis and experimental testing, the real theory combined with the practice of scientific research, the output of scientific research results will be able to guide the performance optimization of industrial products, and organize the guidance methods to form a complete optimization system. For enterprises to provide reference in the design of electric drive system and its working condition matching strategy.

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