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New Energy Vehicle System Optimization on Hill Climbing Algorithm

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Abstract: New energy vehicles(NEV) include three major categories: hybrid vehicles, fuel cell vehicles, and pure electric vehicles. Pure electric vehicles are vehicles that completely use the electrical energy from the on-board battery pack as the driving energy for vehicle driving. The battery pack on pure electric vehicles can use renewable energy to replace traditional fuel, which can not only alleviate the current energy crisis, but also greatly reduce the environmental pollution caused by the automotive industry. Therefore, in the context of global countries paying more and more attention to the ecological environment, NEV, especially pure electric vehicles, are gradually being used and developed more and more. This paper establishes a new energy vehicle system, carries out current optimization for the power battery model of the system, builds a current optimization simulation model based on the hill-climbing algorithm on MATLAB simulation software, compares the current harmonic content of the stator structure of SynRM before and after the current optimization control strategy, and finds that the optimized system can improve the immunity of the electric drive products of new energy electric vehicles.

1. Introduction

NEV are driven partly or fully by energy storage batteries, which is the main feature that distinguishes them from traditional fuel vehicles. As a typical new energy vehicle, NEV have the advantages of being more energy efficient and environmentally friendly than traditional internal combustion engine systems, and therefore have become one of the hot research issues in today's society.

A series of problems such as oil depletion and environmental pollution have led to more and more research on NEV, and many experiments have been conducted to optimize the performance of NEV. For example, some scholars have used the aggregate capacitor thermal model in the ADVISOR simulation toolkit to predict the effect of battery temperature on vehicle performance, which predicts the temperature change of vehicle battery based on conditions such as air cooling flow and battery type, and based on this model, the thermal behavior of the battery module is analyzed and vehicle performance is studied [1]. Overseas research on EMC test technology of electric drive system of NEV is extensive, especially in the area of on-load testing has achieved remarkable results, for example, some scholars have proposed the test method of high and low voltage coupling coefficient of electric drive system of electric and hybrid vehicles, and the relevant EMC tests are conducted in standard certified test chambers, and some optimization schemes are proposed about the problems of on-load testing system but there are still some Some optimization solutions are proposed for the problems of the on-load test system but there are still some deficiencies [2-3]. In summary, the optimized test methods for new energy electric drive systems have been studied, but there is no information on the condition of the tested parts under load, and there is no description of the criteria for using the voltage or current method in the actual test.

This paper firstly introduces the principle of hill climbing algorithm and the stator structure of SynRM, then designs the new energy vehicle power system, electric drive EMC with load test system, and pure power vehicle power battery model, then describes the experimental equipment and method of new energy vehicle optimization based on hill climbing algorithm, and finally analyzes the simulation results of new energy vehicle battery pack current optimization.

2. Basic Overview

2.1. Principle of Hill-Climbing Algorithm

Parameter optimization in engineering has always been an important and tricky problem, and although many effective algorithms have emerged, each has insurmountable drawbacks. In most cases, a single optimization algorithm is not a good solution to the problem, and it is easy to fall into local convergence and poor local search ability is always a pressing problem to be solved. If we can appropriately use the advantages of other algorithms for local optimization search to make up for the shortcomings of a single optimization algorithm, it is undoubtedly an effective means to improve the operation efficiency and solution quality of the optimization algorithm [4-5]. Among them, the hill-climbing method is widely used due to its simple operation and does not require any parameter restrictions.

The hill-climbing algorithm has a larger difference between the random solutions with fixed sequence numbers far from the wave crest and a smaller difference between the random solutions with fixed sequence numbers closer to the wave crest. This characteristic coincides with the trend of the optimal step size. Therefore, the variation of the difference accuracy of the random solutions separated by fixed serial numbers is used to adjust the variation of the step size adaptively so that it is larger at the beginning and smaller at the end to converge to the wave peak at the fastest speed. The specific operation consists of the following steps.

Step 1, arbitrarily generate an initial solution vector K = [k1, k2, k3...] , and calculate its function value.

Step 2, the set of solutions to be selected is generated randomly with the solution K as the center, b (the size of the solution set is taken as 3), and the vectors in B are generated subject to the constraint step.

$$\underset{b\in B}{b} \in \left[k - b\cdot\sigma, k + b\cdot\sigma\right] \tag{1}$$

The initial constraint step, b is the initial constraint step coefficient, which is taken as 0.01.

In step 3, the solution in B with a fitness higher than K and the largest distance from the current solution is used as the new solution to replace the original solution B. Meanwhile, the difference between the two solutions is calculated as the following equation.

$$K_{new} = \max_{b} \left\| b - K_{\underset{b \in B}{old}} \right\| \tag{2}$$

$$L = K_{new} - K_{old} \tag{3}$$

Step 4, the next new solution is still generated around the center of C, but the resulting change is determined by the generation step L.

$$K_{new} = K_{old} + 1/b * L \tag{4}$$

2.2. Structure of SynRM

The stator structure of SynRM can be generally classified into axially stacked and transversely stacked [6]. The axially stacked structure combines two insulating materials with different permeability characteristics, resulting in an increase in the magnetoresistance difference of the SynRM, which results in a higher torque density and lower losses in the SynRM, effectively improving the SynRM power factor. At the same time, the multi-stacked sheet processing can reduce the rotor hysteresis as well as eddy current losses, which are not present in SynRM compared to PMSM that focuses on rotor heating [7]. The advantage of multi-stacked sheet makes the rotor surface of the motor fine and not rough, the magnetic resistance can be smoother undulation changes, effectively improving the dynamic operation performance, which has a good application in the NVH of NEV and other important index performance. Of course, it also has a cumbersome rotor structure processing process, the rotor can not be installed start winding, there are certain restrictions in the high-power application scenario [8]. With the development of technology, these defects and limitations will also be further improved and applied. Transverse laminated rotor structure with air gap magnetic barrier layer. It also has the characteristics of high convex pole rate of axial laminated type, less pulsation, high temperature resistance, etc. The processing process is less difficult, and it is formed by punching laminated type, which has higher mechanical strength and is more suitable for engineering applications, and now most of such structures are used as research objects [9-10].

3. New Energy Vehicle System Design

3.1. New Energy Vehicle Power System Modeling

The establishment of new energy vehicle power system includes three models, which are engine model, motor model and battery model, as shown in Figure 1.

(1) Engine model

There are two main methods to build the engine model: theoretical modeling and practical modeling. But neither is the best choice, and both have certain advantages and disadvantages. Theoretical modeling first analyzes the engine to get a theoretical calculation formula, but the factors considered are less, and the application to practice may lead to deviation in the overall model computing speed due to its own poor operability, but it can accurately reflect the instantaneous response characteristics of the engine [11]; practical modeling is to establish the working characteristics of the engine graph through a large amount of relevant experimental data to reflect its working process, and then use Numerical analysis method is used to derive a set of data from the established characteristic diagram, and finally the interpolation method is used to obtain the function equation of input and output [12]. Compared with theoretical modeling, the operation is relatively simple, and although its accuracy is not as precise as that of theoretical modeling, it is sufficient to meet the needs of the study, so the experimental modeling approach is chosen to establish the engine model.

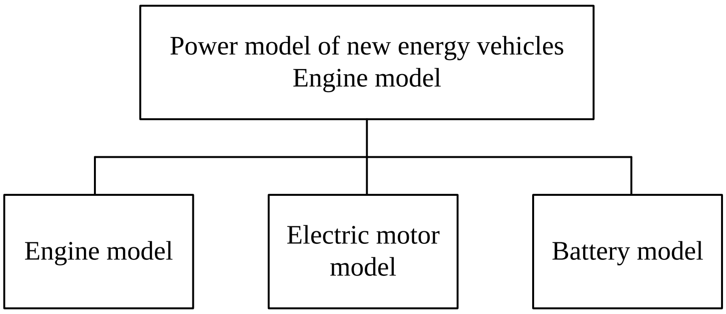

Figure 1. Power model of new energy vehicle

(2) Establishment of the motor model

Since there is no motor in the power system of the transmission vehicle, for the new energy vehicle, the motor is mainly used as a backup power source. The modeling method is similar to the previous engine modeling method, which also needs to use the first-order inertia delay link to change the steady-state output torque into dynamic torque [13].

(3) Establishment of battery model

In the power system of NEV, the battery and the motor together provide energy for the vehicle, which is the main source of vehicle power and more important part of the power section, so it is very meaningful to establish an accurate model for the whole vehicle. Since the battery is a complex process in which chemical reactions occur electrically, the model is also very complex, and the Rint model is chosen to model it, and the battery can be seen as a circuit composed of a power source and a resistor [14-15].

3.2. Electrically Driven EMC with Load Test System

The electric drive EMC on-load test system studied in this paper (designed for electric drive systems for NEV) is capable of being used for EMC radiation and immunity testing of the battery pack, motor controller, DC/DC and motor, and the entire electric drive system [16].

The test stand part of the test system consists of dynamometer motor, speed and torque sensor, coupling, bearing with seat, drive shaft, gear box and base, etc. The semi-electric dark room has part of the stand device inside as well as test table and grounded copper plate [17]. The specifications of the test system are shown in Table 1.The final material selected for this test system is carbon fiber material for the drive shaft through the wall, and the shape of the hole through the wall is square.

The electrical part of the test system contains the electrical cabinet (CA) that supplies power to each unit of the test system, the control unit (CU) that controls the table frame and system operation and monitors the temperature of the table bearing housing, the acquisition unit (AU) that collects experimental data as well as data from the input and output terminals, and the operator console that enables human-computer interaction [18].

Table 1. Test system specifications

Category	Parameter
High voltage supply voltage	1000V
Low voltage supply voltage	10V-300V
Rated current	500A
Table power	220kW
Max. speed	5000rpm
Maximum torque	1000N m
Rotational speed torque sensor	Flis 2500N m

3.3. Power Battery Model of Pure Electric Vehicle

The power battery pack in a pure electric vehicle usually includes many small battery modules, and each battery module is made up of many single cells connected in series and parallel. In the process of vehicle driving, the continuous discharge will make these battery modules release a large amount of heat, and the heat will accumulate in the confined and narrow space of the vehicle, so the performance of each single battery in the battery module will be affected to different degrees. The service life of electric vehicles is seriously affected. Therefore, a reasonable thermal management method should be designed in electric vehicles to take away the heat generated during the use of the power battery pack in time.

4. Experiment of New Energy Vehicle System Optimization Based on Hill Climbing Algorithm

4.1. Main Experimental Equipment

(1) Battery charging and discharging equipment

The battery charging and discharging equipment of the experimental rig is selected from the Decaron battery charging and discharging experimental instrument. Decaron charge/discharge instrument uses bi-directional DC power supply with IGBT technology for AC and DC conversion, with full sine wave energy feedback to the power grid, and uses Pentium industrial microcontroller as the processor internally, with BTS-600 upper computer software, which can simulate the actual working conditions of new energy electric vehicle battery charging and discharging. With two channels, the charging and discharging current range can be from -300A to +300A; the charging and discharging voltage range is from 0 to +600V, and the power is 80kW, which can meet the charging and discharging related experiments of most new energy electric vehicle batteries; the voltage and current experimental accuracy of the equipment is ±0.1% of the range, the data sampling time is <10ms, the current rise/fall time is <10ms, and the charging/discharging conversion time is <10ms. <10ms, charging/discharging conversion time <20ms, and with a switch contactor type emergency stop switch to deal with the occurrence of unexpected situations during the experiment.

(2) Battery testing system

The battery test system can control variables such as current, voltage, power, pulse current, etc. The A/D resolution is ±15bit; the length of the control program can reach more than 3000 steps, and the program can be rotated and repeated; the data can be displayed through the terminal during the experiment, and the data contains time, voltage, current, temperature, etc.

4.2. Analysis of Constant Load Variable Speed Simulation Results

In this paper, we will use MATLAB/Simulink to build a simulation model of pseudo-differential feedback current optimization system based on voltage compensation on the hill-climbing search algorithm based on virtual signal injection. The simulation model is combined with different working condition scenarios for different experiments in order to compare the harmonic content in the SynRM stator current before and after taking the current optimization control strategy.

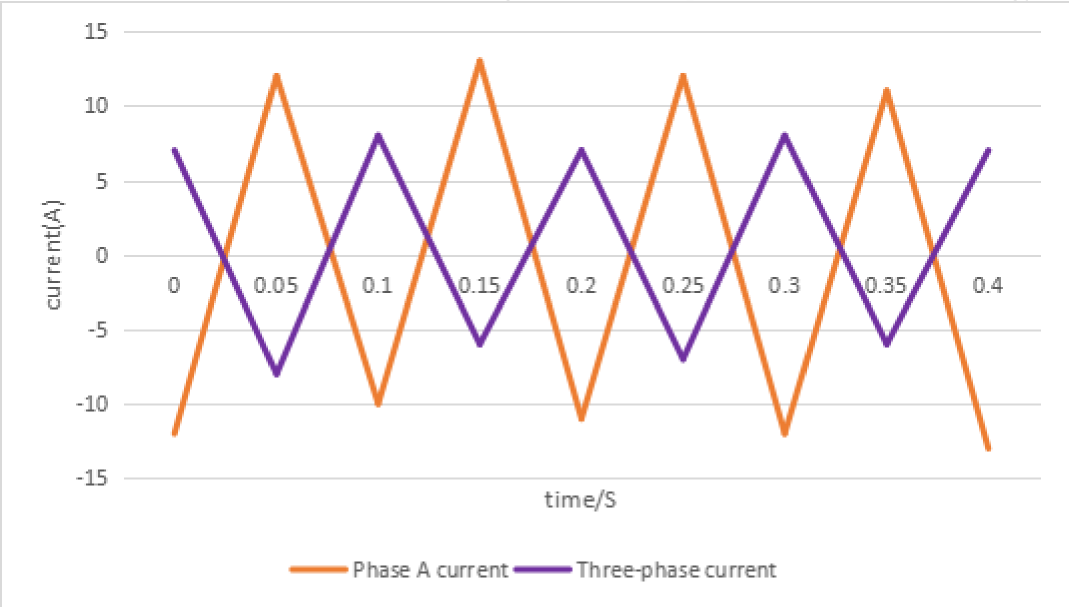

Figure 2. Constant load 5N-m variable speed A-phase current and variable speed three-phase current

As shown in Figure 2, the A-phase current waveform and the three-phase waveform are respectively shown in the constant load 5N-m variable speed control operation, from which it can be seen that the current waveform shows more regular fluctuations during the whole process from the start of the motor to the stable operation and then to the pull-up speed, and the harmonic content and ripple in them are relatively ideal, and the convergence time is faster and the response time is shorter.

Table 2. Current spectrum

	1	2	3	4	5	6	7	8	9
Before optimization	100	11.2	9.6 15.7	16.3	10.5	14.1	2.3	7.4	
After Optimization	5.6	4.5	6.1	3.8	6.5	2.7	4.2	3.4	2.8

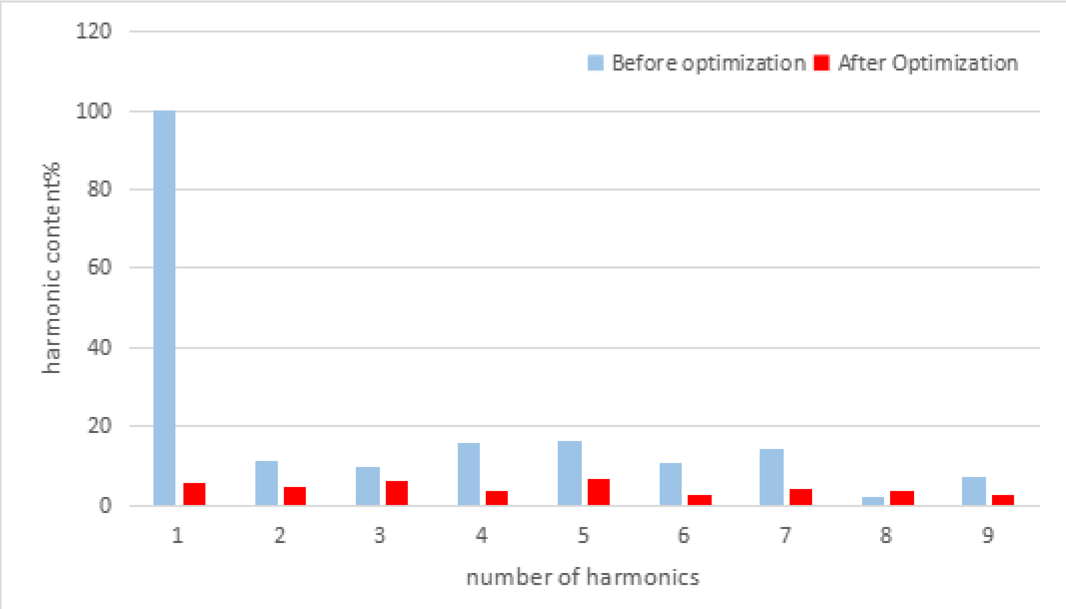

Figure 3. A-phase current spectrum before and after optimization

Table 2 and Fig. 3 show the comparison of the A-phase current spectrum before and after the optimized current. Before optimization using the current optimization control strategy, the 3rd harmonic content appeared at about 10%, and the 3rd harmonic content was about 15%, while the harmonic content of the current after optimization were reduced to less than 10%. The current obtained after using the current optimization control strategy tends to be more ideal sine wave, which better improves the harmonic content in the SynRM stator current and weakens various disturbances, which is beneficial to the SynRM In the new energy electric drive and other products require higher utilization effect, especially in the electric vehicle immunity index.

5. Conclusion

With the development of the automotive industry towards electrification, intelligence and networking, the number of electric electronic devices applied in automobiles is increasing, and the electromagnetic compatibility of automobiles is receiving more and more attention in their development process. The electric drive system is the power source of the new energy vehicle, and it is a serious threat to the safety and reliability of the vehicle due to its electromagnetic interference source alone. In this regard, this paper optimizes the new energy electric vehicle system, and in order to improve the performance of the electric drive system, the optimization results of the current optimization control strategy are analyzed, showing that the anti-interference of the electric drive products can be improved after using the optimization strategy.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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