Original Paper

Parameter Optimization of Pure Electric Vehicle Power System Based on Genetic Algorithm

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Abstract

In this paper, the ADVISOR software was used to establish a complete vehicle model of an electric vehicle, and the model was verified by CYC_NEDC under European urban conditions to meet the requirements. The maximum power of the driving motor, the speed ratio of the transmission system and the capacity of the storage battery are taken as the optimization objectives to carry out multi-objective optimization. Connect the model built by genetic algorithm and ADVISOR, run the program to simulate the two together, and get the result of parameter optimization of dynamic system. Through the simulation analysis and comparison under CYC_NEDC cycle conditions, the maximum speed, maximum climb slope, acceleration time and other dynamic performance parameters of this electric vehicle are effectively improved after optimization.

Keywords

Genetic Algorithm, Pure Electric Vehicle, Power System, parameter optimizat

1. Introduction

For pure electric vehicles, how to design the power system and optimize the parameters so that they can achieve the best power performance under different driving conditions, meet the maximum speed, acceleration and climbing requirements. At the same time, choose an effective way to optimize and match the corresponding performance parameters, so that under the premise of meeting the requirements, each performance index more. At present, for the optimization of power system parameters of pure electric vehicle, the transmission speed ratio is mainly chosen as the optimization design variable. However, only optimizing the transmission speed of pure electric vehicle has some limitations to improve the vehicle performance. Therefore, this article has carried on the improvement

in this aspect.

2. Establishment of Full Vehicle Model of Pure Electric Vehicle

2.1 Parameter Selection and Matching

This paper selects a pure electric vehicle for research, its basic parameters and performance indicators as shown in Table 1.

Table 1. Basic Parameters and Performance Requirements of Pure Electric Vehicle

Vehicle Parameters/performance indicators	Numerical value
Full load mass（kg）	1500
Wheelbase（m）	2.45
Conversion Coefficient of Rotary Mass	1.04
Rolling radius of tire（m）	0.277
Air Drag Coefficient	0.35
Windward area（m2）	2.1
Coefficient of rolling resistance	0.019
Maximum speed	>120km/h
Acceleration time	0~50km/m Acceleration time<8s 0~100km/m Acceleration time<15s
Maximum climb	25%（At 20 km/h）
Driving Range	≧120km（at constant speed：60 Km/h）

According to the basic parameters of the whole vehicle, the selection of the battery and the motor and the calculation of the transmission ratio of the transmission system, the matching result of the power system parameters is as shown in Table 2.

Table 2. Power System Parameters Match

Main structure of power system	Parameters	Parameter value
Lithium ion battery	Number of Voltage/capacity (v/Ah) of monomer	3.6/5 26 and 47 strings
Permanent magnet synchronous motor	Peak/rated power（kw）	50/30
	Peak Speed/rated speed（r/min）	8000/3000
	Peak Torque（N.m）	180
Main reducer	Speed ratio	6.79

2.2 Establishment and Verification of Vehicle Motion Module

According to the structure of Ev and the step-by-step transfer mode of power flow, the whole ev simulation model is established with ADVISOR software, as shown in Figure 1. The whole vehicle motion module is established by backward simulation after analyzing the vehicle motion equation and all the resistance during the vehicle running, as shown in Figure 2.
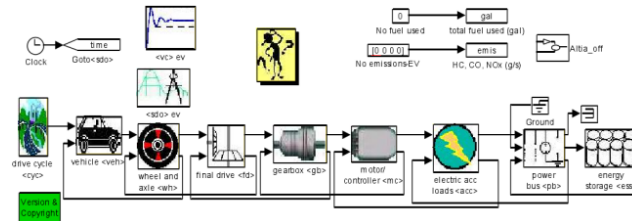

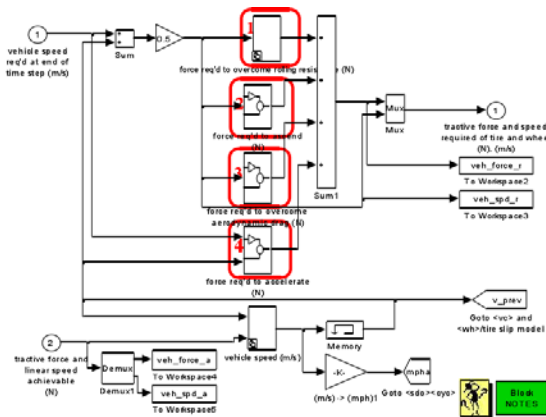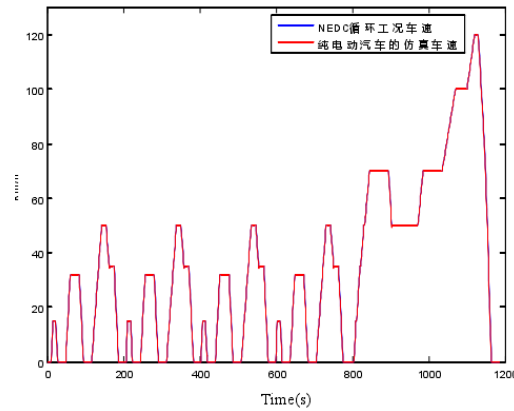**Figure 1. Simulation Model of Pure Electric Vehicle**

Figure 2. Vehicle Motion Module

On the basis of the whole vehicle model of pure electric vehicle (EV), the current general test condition of EV, CYC_NEDC, Figure 3 is selected to simulate and analyze. At the same time, the dynamic system performance parameter values are shown in Table 3.

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Figure 3. The Following Diagram of the Vehicle Speed to the Required Speed CYC_NEDC

Table 3. CYC_NEDC Analysis of Simulation Results under Cyclic Operating Conditions

Performance Index	Numerical value
Maximum speed	124.6km/h
Acceleration time	0~50km/h：4.7s
	0~100km/h：14s
Maximum climb	26.9%（The speed is20km/h）

By comparing the simulation results of the performance indexes in Table 3 with the requirements of the performance indexes in Table 1, it is concluded that the dynamic performance indexes of the electric vehicle model meet the design requirements under CYC cycle working condition, and the real-time vehicle speed and the circulation condition request the speed to follow the situation to be good. Therefore, the calculated matching parameters of EV power system meet the requirements of power performance.

3. Establishment of Parameter Optimization Model of Power System Based on Genetic Algorithm

On the basis of the correct modeling, the parameters of the model are optimized and analyzed to realize the optimization of the dynamic system. In this paper, genetic algorithm is used to optimize the power system parameters of EV. Firstly, the parameter optimization model is established.

3.1 Modeling

3.1.1 Selected Variable

In this paper, the maximum power Pmax of the drive motor, the transmission ratio I 0 and the battery capacity C are selected as optimization variables to ensure the optimal dynamic performance of the vehicle during the driving process, the selected variables are as follows:

$$X = [x_1, x_2, x_3] = [P_{max}, i_0, C] \tag{1}$$

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3.1.2 Establish an Optimal Objective Function

The optimization objectives of power performance of pure electric vehicle mainly include the vehicle's maximum speed UAMAX, maximum climbing degree Imax, and minimum acceleration time T. Compared with the first two indexes, the acceleration time can better reflect the comprehensive power performance of the vehicle. Therefore, the acceleration time is chosen as the optimization target to measure the dynamic performance:

$$f_t(x) = t(x)$$

(2)

3.1.3 Establish Constraints for Optimization

On the premise of considering the optimization goal synthetically, the vehicle should also meet the vehicle performance index (Table 2) and the driving requirements, therefore, the following constraints are established:

1) Meet the constraints of the maximum speed

$$g_1(x) = \frac{0.377 r n_{max}}{i_0} - 100 \geq 0$$

(3)

2) The constraint condition of the maximum climbing degree is satisfied

$$g_2(x) = \arcsin \frac{F_t - F_f - F_w}{mg} - 0.25 \geq 0$$

(4)

3) The acceleration time condition is satisfied

$$g_4(x) = 15 - \int_0^{100} \frac{\delta m u}{F_t - F_f - F_w} du \geq 0$$

(5)

$$g_3(x) = 8 - \int_0^{50} \frac{\delta m u}{F_t - F_f - F_w} du \geq 0$$

(6)

4) Battery Life Constraints

$$g_5(x) = \frac{3600 W \zeta_{soc} \eta}{mgf + \frac{C_D A u_a^2}{21.15}} - 120 \geq 0$$

(7)

5) It meets the restriction condition of vehicle normal running and adhesion performance

$$F_{X max} = \frac{T_{max} i_0 \eta}{r} \leq F_z \varphi$$

(8)

$$g_5(x) = F_Z \varphi - \frac{T_{max} i_0 \eta}{r} \geq 0$$

3.2 Analog Operation

Based on the above modeling, the ADVISOR simulation model is called by genetic algorithm, and the ADVISOR performance is calculated by assigning optimization variables, and the optimization

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objective function is calculated, optimization complete.

The working process of power system parameter optimization of pure electric vehicle is shown in Figure 4.
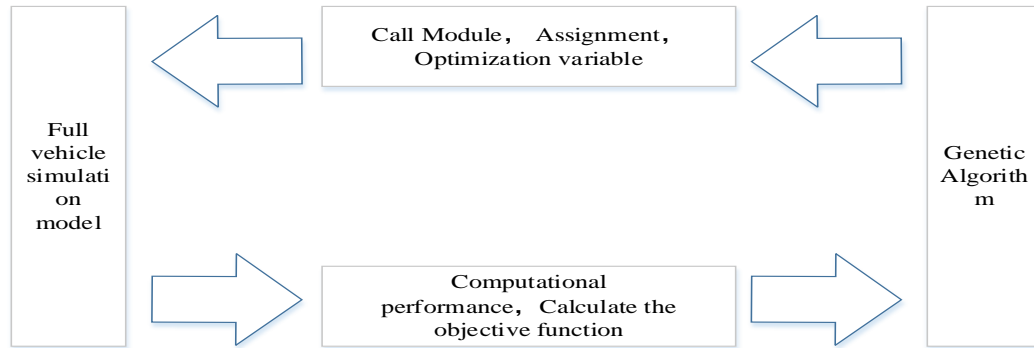
Figure 4. Working Process of Power System Parameter Optimization of Pure Electric Vehicle

3.3 Optimization Solution and Analysis

3.3.1 SET GENETIC ALGORITHM RUN parameters

According to the rules of genetic algorithm and the characteristics of optimization target, the parameters of optimization model are set as follows:

Table4. Optimization of Model Parameters

| Model parameter	Numerical value
Population size	30
Maximum Evolution Algebra	30
Cross probability	0.9
Mutation probability	0.9

After determining the basic parameters of the Genetic Algorithm, the optimization program of the Genetic Algorithm is written, which connects the genetic algorithm and the ADVISOR model.

Table 5. Optimization Results of Power System Parameters for Pure Electric Vehicle

Optimization parameter	Maximum power	Electric capacity	Transmission ratio
3	48.6kw	135Ah	6.61

3.2.2 Optimization Result Analysis

The optimized value of variables is substituted into the ADVISOR to simulate the whole vehicle, and the simulation results under CYC cycling condition are shown in Figure 5.

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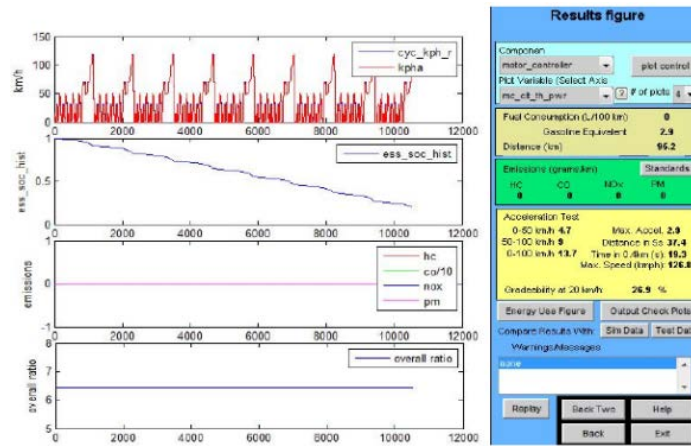
Figure 5. Optimization Results of Power System Parameters for Pure Electric Vehicle

Table 6 shows the comparison of power performance indexes before and after the optimization of power system parameters of EV. After the optimization of power system parameters of EV, the maximum speed increased from 124.6 km/h to 126.8 km/h, and the maximum speed increased by 1.77%. Figure 6 shows the speed comparison curve before and after optimization under CYC cycle conditions. The acceleration time before and after optimization was reduced from 14s to 13.7 S and the acceleration time was reduced by 2.15%. After optimization, the acceleration performance was improved. In the aspect of hill climbing, the maximum hill climbing degree of the optimized ev was 27.6%, which was 2.6% higher than that before the optimization.

Table 6. Comparison of Power Performance of Pure Electric Vehicle before and after Optimization

Performance Index	Before optimization	After optimization	Rate of change
Maximum speed	124.6km/h	126.8km/h	+1.77%
Acceleration time of 0~100 km/h	14s	13.7s	+2.15%
Maximum climb	26.9%	27.6%	+2.6%
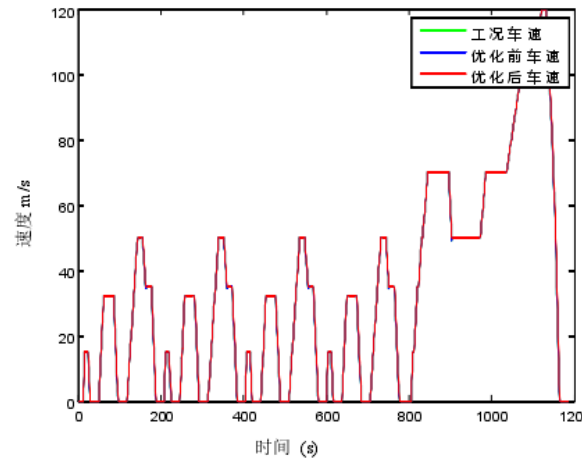
Figure 6. CYC_NEDC Optimizing the Comparison Curve of Vehicle Speed before and after Cycle Operation

4. Result Analysis

In this paper, the multi-objective optimization of the power system is carried out by considering the relationship among the components of the powertrain, using the rules of genetic algorithm and the requirements of the optimization objective. Using the established vehicle model to carry on the simulation analysis to the optimized power parameter, obtains this vehicle power performance to enhance obviously. In order to provide the basis for the vehicle design in the next step, the simulation running analysis of pure electric vehicle is carried out under the specific working condition, and then the optimum power parameter matching is determined.

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