Original Research Article

Design and computer simulation of electric vehicle braking energy recovery system

Xianhuan Wu[*Corresponding Author]

Wuhan Business University, Wuhan, Hubei, 430056, China

Abstract: Traditional fuel vehicles generate a lot of energy during driving, which leads to problems such as deterioration of vehicle braking performance and frequent road safety hazards. Therefore, how to efficiently use electric vehicles to overcome the huge consumption and environmental pollution caused by traditional power passenger vehicles is one of the hot topics of future research.

Keywords: Electric vehicle; Energy recovery system; Vehicle braking performance

1. Introduction

With the development of economy, cars have become an indispensable means of transportation for people. However, traditional fuel engines have serious emissions, high noise, and insufficient endurance. These problems lead to various failures in the use of electric vehicles. Therefore, it is of great significance to study a new type of high-efficiency braking energy recovery system[1].

2. Theoretical analysis of braking energy recovery system

2.1. Recovery and utilization of braking energy under driving conditions

Assuming that the braking force distribution on the front and rear wheels follows the I curve, and the resistance is neglected, the braking force applied to the front and rear wheels can be expressed as shown in formulas (1) and (2):

$$F_{bf} = jM(L_b + h_g j/g)/L \tag{1}$$

$$F_{br} = jM(L_a - h_g j/g)/L \tag{2}$$

2.2. Braking theory analysis

According to ECER13 and GB 12676 stipulated in the braking adhesion coefficient, the use of legal requirements and automobile braking theory are shown in formulas (3), (4) and (5). According to the vehicle quality and brake parameters listed in **Table 1**, the curve I, the β curve, the f line and the r line of the front and rear wheel distribution of mechanical hydraulic braking force at no load and full load are derived, and the minimum braking requirement curve on the rear wheels stipulated by ECE regulations[3].

$$F_f = \frac{Mg}{L}(b + zh_g)j \tag{3}$$

$$F_r = \frac{Mg}{L}(a - zh_g)j \tag{4}$$

$$\beta = \frac{d_1^2 \cdot BEF_1 \cdot r_1}{d_1^2 \cdot BEF_1 \cdot r_1 + d_2^2 \cdot BEF_2 \cdot r_2} \tag{5}$$

Table 1. Vehicle quality and brake parameters.

Project	Codename	Unit	Parameter
No-load mass	M1	kg	1330
Full load quality	M2	kg	1705
Wheelbase	L	mm	2500
Horizontal distance from unloaded rear axle to center of mass	b1	mm	1421
Horizontal distance from fully loaded rear axle to center of mass	b2	mm	1292
No-load center of mass height	hg1	mm	485
Fully loaded centroid height	hg2	mm	525
Front/rear brake braking radius	r1/r2	mm	102/110
Friction coefficient of front brake brake pad	f1		0.4
Rear brake performance factor	BEF2		2.2
Front/rear wheel cylinder diameter	d1/d2	mm	53.97/20.64

3. Design of braking energy recovery system

3.1. Analysis of braking torque application of braking energy recovery system

Compared with the original braking system, the parallel braking energy recovery system has the advantages of simplicity, directness and low cost. It can effectively improve energy economy without large-scale changes to the original vehicle structure, which has a good prospect for batch applications. On this basis, it is proposed that the braking torque application analysis for the coordinated control of the feedback braking force is proposed in the braking energy recovery control according to the driving demand and the vehicle state[4].

3.2. Braking energy recovery vehicle control method

In both coasting and braking conditions, the vehicle controller VCU sends a torque command to the motor controller MCU1. Considering that the motor's braking energy recovery torque is limited by the battery's allowable pulse charging and charging capacity, the value of the motor's braking torque command needs to be calculated by the process shown in Figure 1 to obtain the initial value of the braking torque T[5].

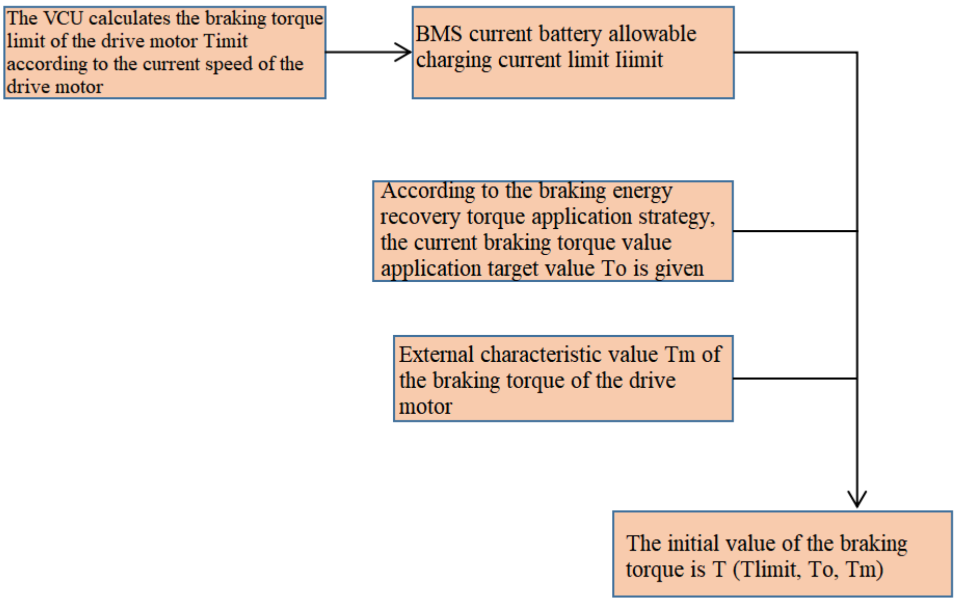

Figure 1. Calculation process of motor braking torque.

The motor braking torque application process is divided into three stages, namely, soft cut-in, deep feedback and soft withdrawal. According to the three stages, the external characteristic value of the electric mechanism is calculated[6].

The designed braking energy recovery vehicle control method mainly needs to be considered and improved:

(1) The size and time that the battery is allowed to receive current under different SOCs and different temperatures.

(2) Stability and smoothness when the two modes of drive motor drive and power generation are switched.

(3) The size of the applied electric torque and the applicability and stability of the energy recovery system under different vehicle speeds and working conditions.

(4) Optimize the BMS control program to ensure that the allowable charging current and duration required by the system under different temperatures and SOCs are accurate and effective.

(5) Verify the stability of the braking energy recovery system in various working conditions such as long downhill sections in mountainous areas and winter[7].

3.3. Parallel braking energy recovery design

According to the driver's accelerator pedal signal, brake pedal signal, gear signal, electric brake strength adjustable paddles and vehicle operating state parameters by the VCU, it sends a brake energy recovery electric brake torque command to the MCU according to the brake energy recovery control strategy.

The position of the torque control function in the vehicle control function module is the application layer module as shown in the figure below. This is mainly reflected in the four module functions of working condition judgment, torque demand, torque limit and torque gradient. As shown in Figure 4 below, the VCU software model architecture diagram[9].

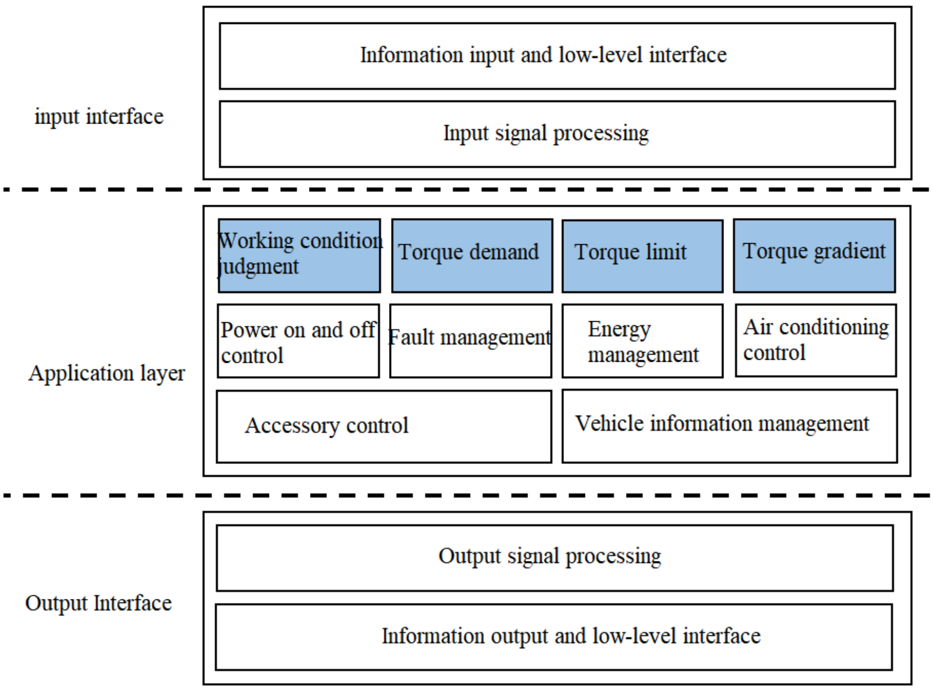

Figure 2. VCU software model architecture diagram.

Based on the traditional ABS control, the energy recovery torque exit mechanism is added to the integrated adjustment of the feedback braking force. This can increase the response speed of the anti-lock brake control and improve the control effect. At the same time, it can also recover as much energy as possible[10].

The coordinated control mechanism of the parallel energy recovery system and ABS is fully considered to judge the working status of the anti-lock braking system. If it sends to the vehicle controller that it has been activated or fails, it will interrupt and exit the braking energy recovery control.

4. Conclusion

With the development of the global economy, cars have become one of the indispensable means of transportation for people. However, traditional fuel vehicles have many shortcomings. For example, the battery has long charging time and low energy density. This requires continuous research and improvement by researchers.

Acknowledgments

2018 Scientific Research Project of Wuhan Business University (Research on Control Strategy of Brake Energy Recovery System for Pure Electric Vehicle Based on Simulink-Advisor Co-simulation, 2018KY019) .

References

[1] Zhang Xu, Yu Shijun. Design of braking energy recovery system for electric vehicles [J]. Hebei Agricultural Machinery, 2016: 50-50.
[2] Yu Rui. Design of braking energy recovery system for electric bicycles [J]. Exam Weekly, 2012: 113-113.
[3] Yan Wenlong, Fu Chengwei. Electric vehicle operation simulation and super capacitor energy recovery system design [J]. Modern Electronic Technology, 2014: 150-152+156.
[4] Li Suhua. The design and simulation research of pure electric vehicle drive system [J]. Machinery Design and Manufacturing, 2016: 48-50+54.
[5] Li Yongjian, Zhao Zuoxi. Design and simulation of electric drive system controller for pure electric vehicle [J]. Journal of Beijing Polytechnic Institute, 2018: 14-19.
[6] Chen Peng, Wang Shanfeng. Research on Braking Energy Recovery System of Electric Vehicles [J]. Full Text Edition: Engineering Technology, 2016: 219.
[7] Yu Chuli, Xin Minghua. Braking energy recovery simulation of electric vehicles based on Cruise BlackBox [J]. 《Automotive Engineers》, 2016: 25-27.
[8] Wang Xipeng, Pan Shenghui. Design and Simulation of Electric Braking System of Pure Electric Vehicles [J]. Journal of Dongguan University of Technology, 2016: 107-111.