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Torque Management Strategy of Pure Electric Vehicle Based On Fuzzy Control

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Abstract: *The electric motor of pure electric vehicle is the direct power source of the automobile. This paper analyzes the current method of electric vehicle torque control, and proposes a torque management strategy for pure electric vehicle based on fuzzy control, and uses Matlab/Simulink to build a strategy model. A vehicle model of an electric vehicle was established using AVL Cruise, and a software co-simulation was performed. Simulation results show that the use of fuzzy control torque management strategy improves the car's economy.*
Keywords: *pure electric vehicle; fuzzy control; torque management; modeling and simulation*

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I. Introduction

The current development of pure electric vehicles in the world is in full swing. Although the battery life of pure electric vehicles has been criticized for a long time, with the advantages of green pollution-free, excellent dynamics and comfort, as well as government financial subsidies, laws and regulations to encourage, pure electric vehicles have also become more and more popular and accepted. In the technical background of the battery technology can not be delayed, relevant optimization of the battery energy consumption is particularly important.

The battery-related controls include vehicle control, battery management, and brake energy recovery. The vehicle control is to process the driver's operation signals, motor control signals, battery management signals, and communication system signals, and output control signals for controlled objects such as motors and batteries; battery management is the management of the battery's charge and discharge in order to ensure that it achieves the best use performance; braking energy recovery is to convert the kinetic energy of braking into electricity, stored in the battery, to achieve the effect of energy recovery.

This article starts with the torque management in the vehicle control, analyzes and optimizes the torque management strategy.

II. Torque Management Analysis Of Pure Electric Vehicles

Pure electric vehicle torque management strategy is generally to send the driver's pedal signal and vehicle driving status signal to the torque control module, the torque control module through the analysis of the input signal, find the motor torque MAP map, and then the analyzed torque signal command is sent to the motor. As shown in Figure 2-1.

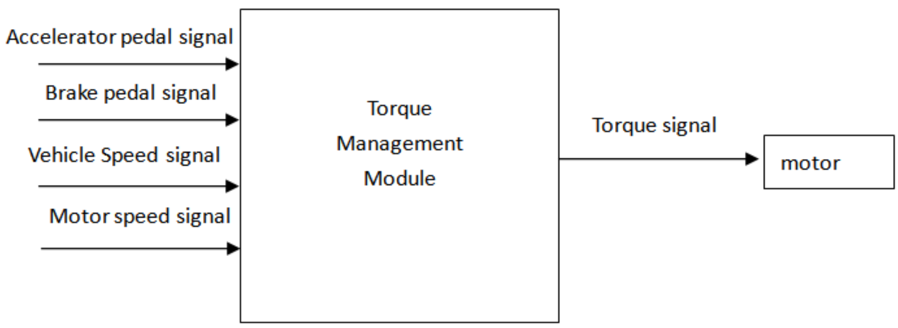

Figure 2-1 Torque management

2.1 General Torque Management Strategy

Figure 2-2 is the torque diagram of a pure electric vehicle motor. The black line shows the rated torque curve of the motor. In the red line, the area A is the constant torque area of the motor, and the area B is the constant power area. Usually, the output torque of the motor controlled by the control signal is linearly proportional to the opening of the pedal, as shown in Figure 2-3. That is, the percentage of accelerator opening corresponds to an equal percentage of the rated torque.

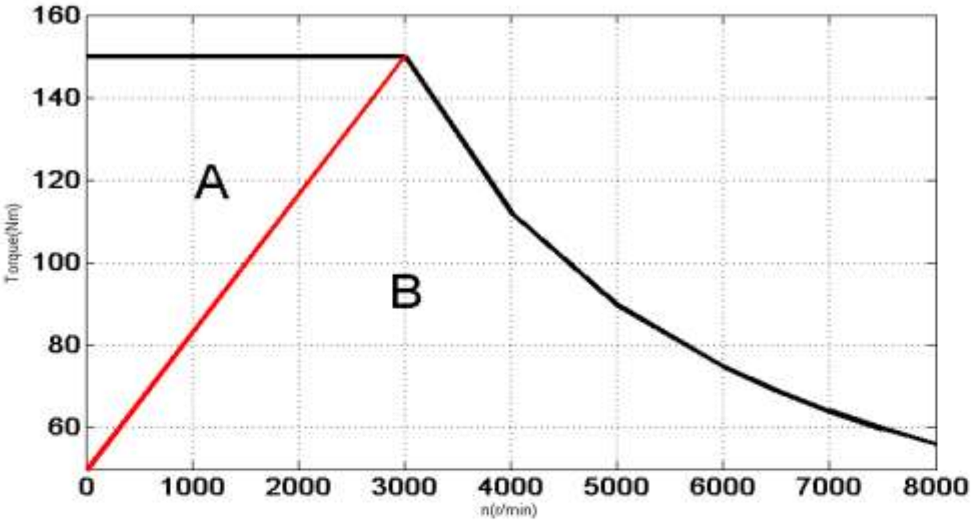

Figure 2-2 Rated torque of a certain electric vehicle motor

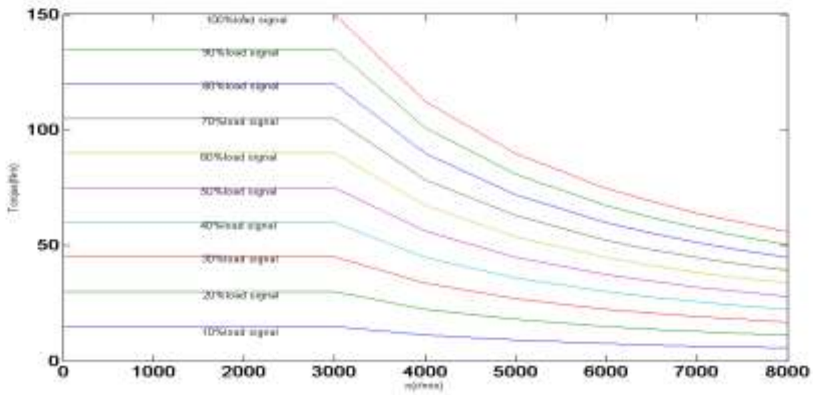

Figure 2-3 Linear Torque Control

This control method [1] only uses the accelerator pedal opening as the main reference for torque output, and the control is simple. The control strategy is a one-to-one correspondence between the accelerator pedal opening percentage and the maximum torque percentage. For example, when the accelerator pedal opening is 50%, the torque output is 50% of the motor rated torque; when the accelerator pedal opening is 70%, the torque output is 70% of the nominal motor torque. The relationship between the accelerator pedal signal of this method and the motor load factor is shown in Figure 2-4.

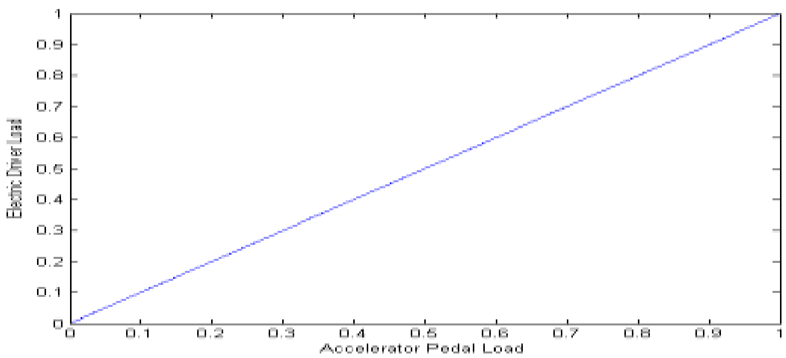

Figure 2-4 Relationship between negative pedal load and motor load in normal mode

2.2 Dynamic Torque Management Strategy

In order to meet the driver's demand for rapid acceleration, the power mode is generally set in the torque management mode. In the power mode, the torque output strategy can be summarized as: outputting a greater motor torque at a lower accelerator opening. Compared with the general torque management strategy, the dynamic torque management strategy makes the vehicle's acceleration response faster and the acceleration performance better. The relationship between the accelerator pedal signal and the motor load factor in this method is shown in Figure 2-5.

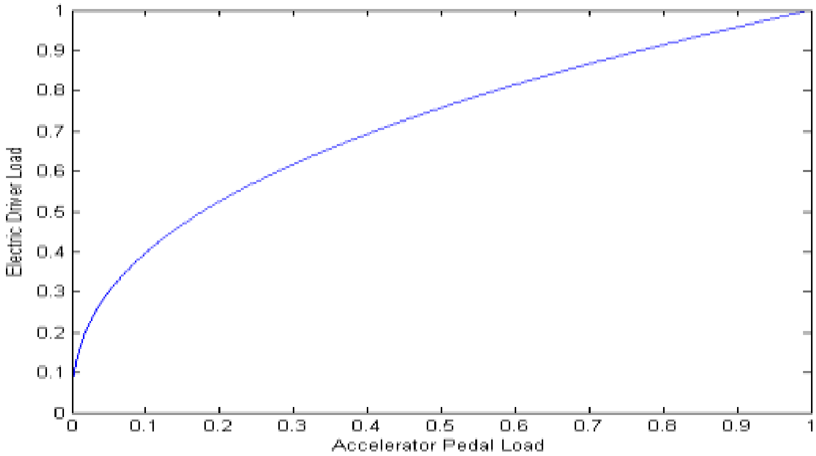

Figure 2-5 Relationship between accelerator pedal negative load and motor load in power mode

In the power mode, the output torque of the motor is larger than that of the normal mode, so the battery discharge current is larger and the mileage of the vehicle will be reduced.

2.3 Economic Torque Management Strategy

In the event of traffic congestion or when the driver does not need strong acceleration, an economical torque management strategy is generally used. Compared with general torque management strategy and dynamic torque management strategy, economic torque management strategy has smaller output torque at the same accelerator pedal opening speed, slower acceleration, and lower battery discharge current, which helps to improve the cruising range of the battery. The relationship between accelerator pedal signal load and motor load in economy mode is shown in Figure 2-6.

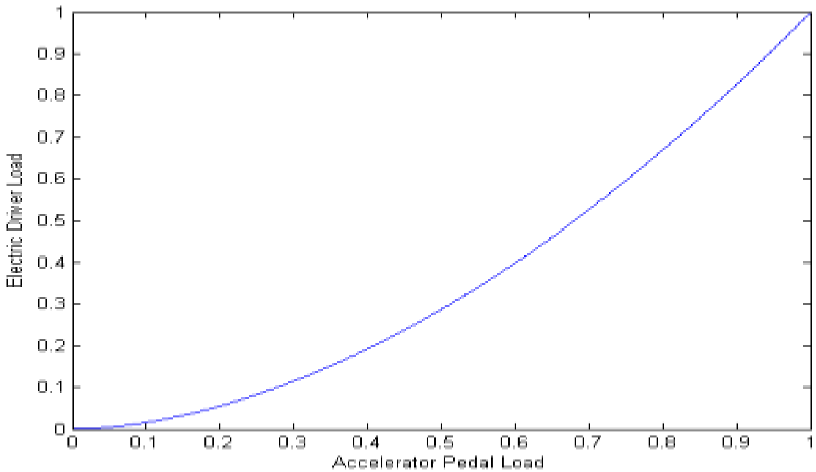

Figure 2-6 Relationship between accelerator pedal negative load and motor load in economy mode

III. Torque Management Fuzzy Control Method

In Chapter 2, the driver can manually switch three different torque output strategies according to his driving needs; also can be based on the driver's operating signals, to achieve the driver's operating intent recognition, such as the driver depresses the accelerator pedal Acceleration, to automatically switch the torque output strategy, eliminating the need for manual switching trouble.

This paper uses the fuzzy control method to identify the driver's intention of operation [2]. Different from the existing methods, the output of the fuzzy control achieves the automatic adjustment of the motor load curve. The curve adjustment is shown in Figure 3-1.

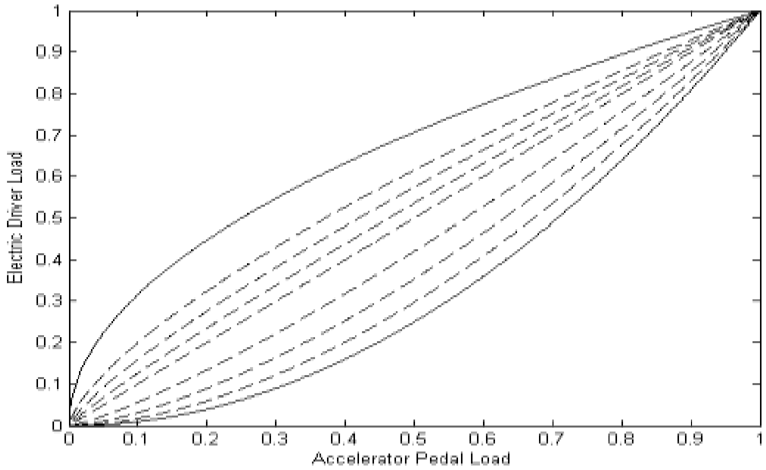

Figure 3-1 Adjustment of load curve

3.1 Operation Intention Recognition and Curve Parameter Adjustment

As shown in Fig. 3-2, the accelerator pedal signal and the accelerator pedal change rate [3] are used as the fuzzy control input signal, and the parameters of the motor load curve are used as output signals to establish the fuzzy control in the fuzzy toolbox file.

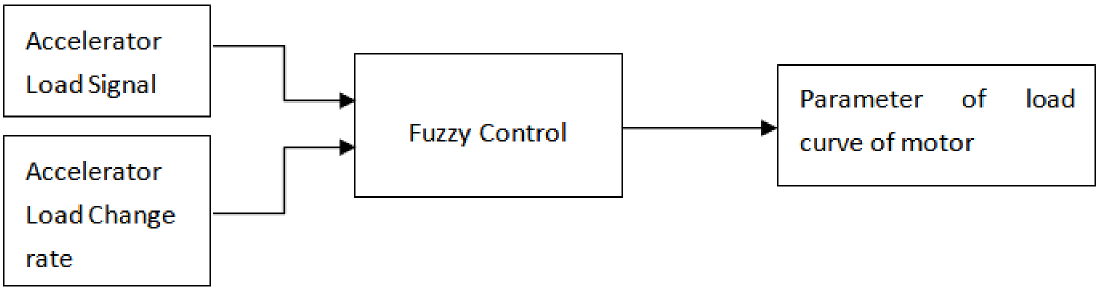

Figure 3-2 Fuzzy Control Signal

The acceleration signal is blurred to "low, medium and high". The membership function type is "trimf" and the value range is 0 to 1, as shown in Figure 3-3.

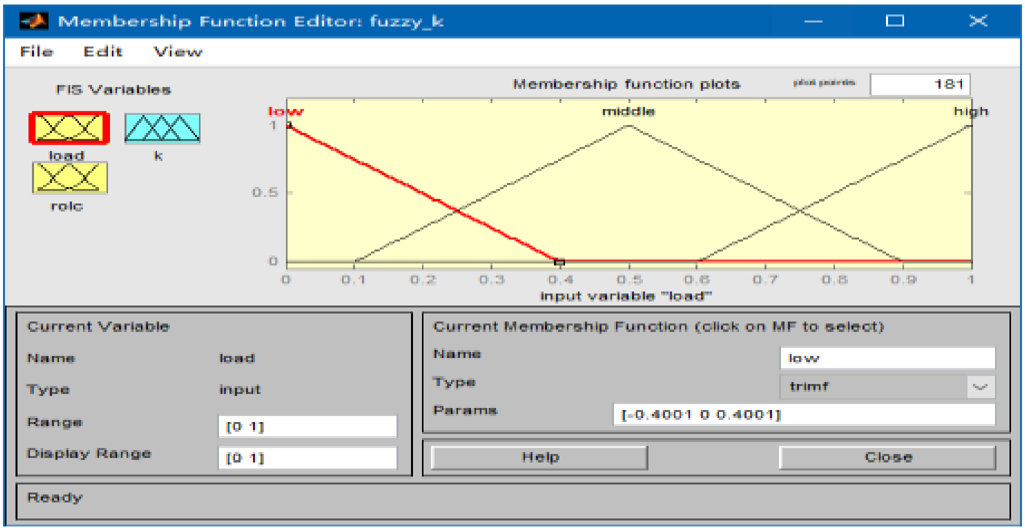

Figure 3-3 Fuzzing of the accelerator pedal signal

The rate of change of the accelerator pedal is fuzzified to "fuda,fuz,zero,zz,zd". The membership function type is "trimf" and the value range is -2 to 2, as shown in Figure 3-4. When the rate of change of the accelerator pedal is greater than 2 or less than -2, the rate of change is set to 2 or -2.

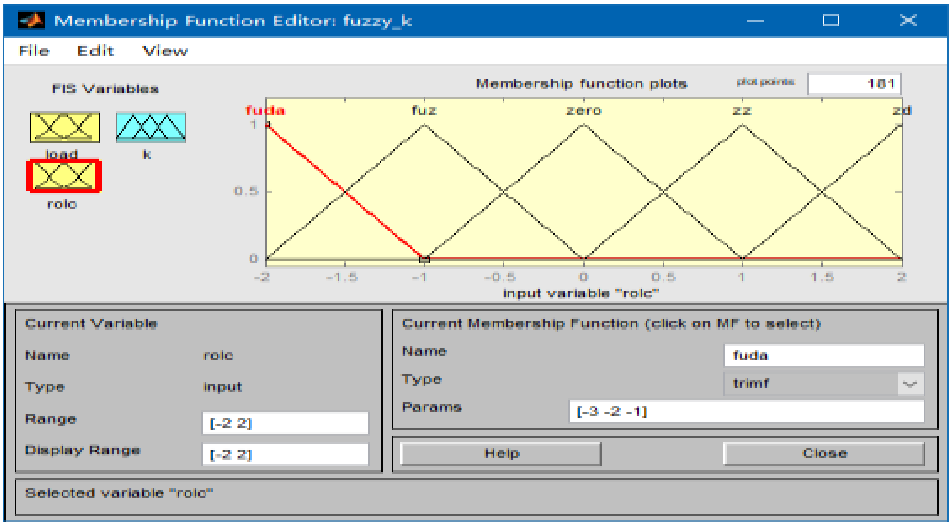

Figure 3-4 Fuzzification of the rate of change of accelerator pedal signal

The output signal, that is, the parameter of the accelerator pedal load signal and the motor load curve is blurred into "small, medium, and large". The membership function is set to "trimf", and the range of values is set to 0.5 to 1.5. As shown in Figure 3-5. [4]

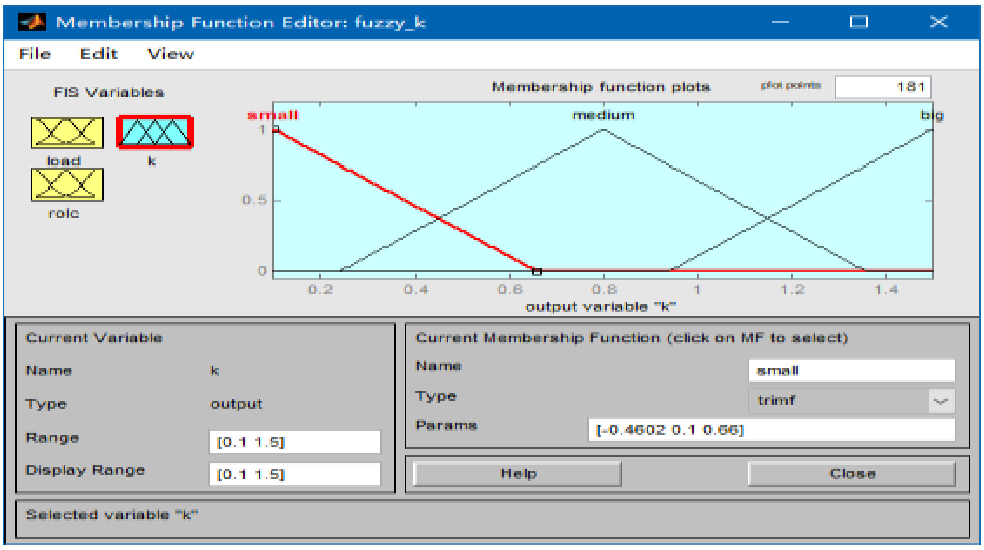

Figure 3-5 Curve parameter fuzzification

3.2 Setting of fuzzy rules

In general, when the driver depresses the pedal at a faster speed, the output torque is expected to be larger, and vice versa. In the initial stage of the pedal depressing, the torque output is expected to change slower in order to ensure the smoothness of the acceleration, amd then becomes faster; when the driver releases the pedal, the torque change should be slower from the initial release of 100% opening to make the ride smoother and faster in the middle and later stages in response to the driver's operation demand. The smaller the value of the fuzzy output parameter, the steeper the torque output curve and the faster the torque change. Conversely, the larger the value, the slower the torque output curve and the slower the torque change. According to these operating rules, 15 fuzzy rules are established, as shown in Figure 3-6.

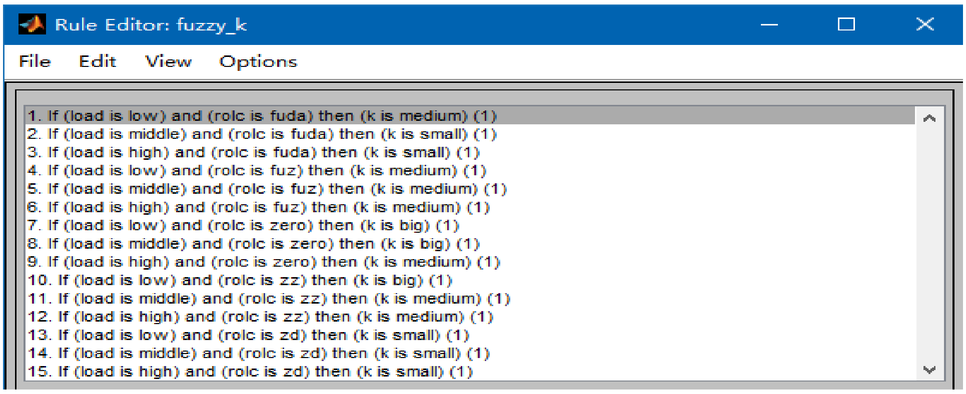

Figure 3-6 Fuzzy rules

IV. Modeling And Simulation Analysis

4.1Simulink Fuzzy Control Model

The fuzzy control management strategy model for establishing torque in Simulink is shown in Figure 4-1.

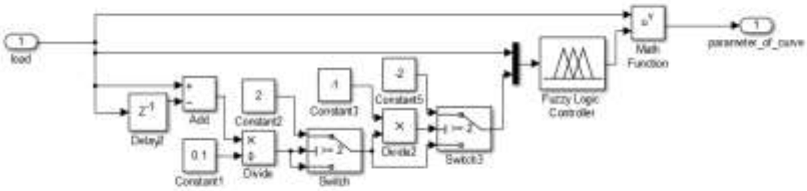

Figure 4-1 Fuzzy Control Model

Based on this, adding the brake pedal signal, motor speed signal, establish a torque management control model, as shown in Figure 4-2. When the brake pedal signal is greater than 0, the brake mode is entered; when the brake pedal signal is equal to 0, the motor torque is output according to the accelerator pedal signal and the motor rotation speed signal. The model without the fuzzy torque control module is shown in Figure 4-3.

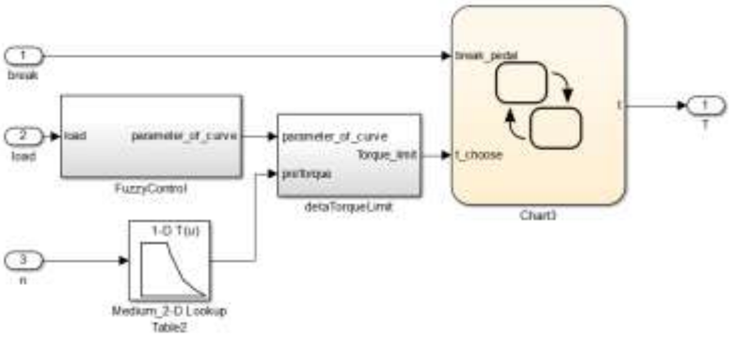

Figure 4-2 Fuzzy Torque Management Model

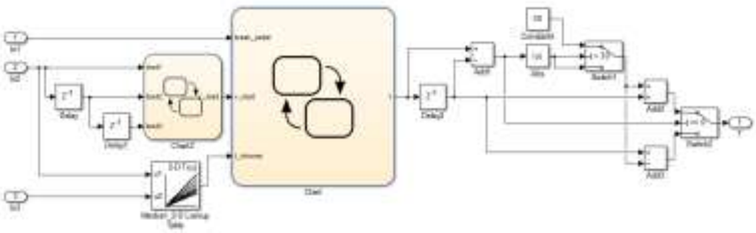

Figure 4-3 Torque management model without fuzzy control

After the model is built, the dll file is compiled for subsequent co-simulation.

4.2 AVL Cruise Vehicle Model

Establishing a pure electric vehicle model in AVL Cruise is shown in Figure 4-4. Among them, "Matlab Dll" module inputs brake pedal signal, accelerator pedal signal, and motor speed signal from the "Cookpit", and leads out the torque signal to "eDrive".

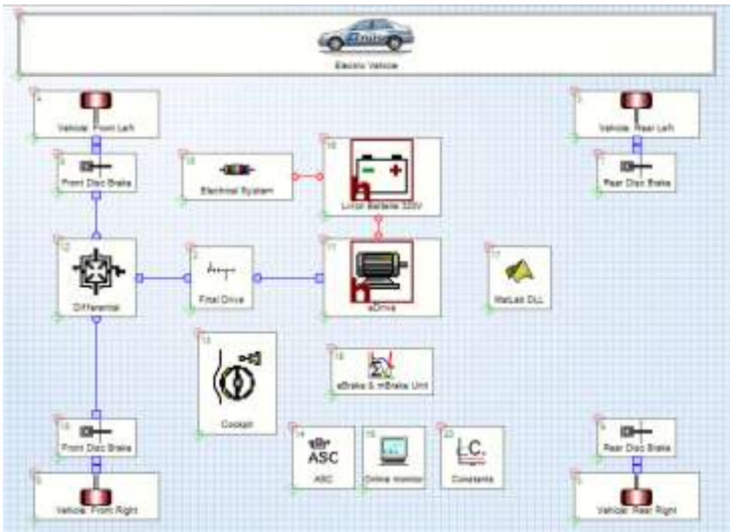

Figure 4-4 AVL Cruise Vehicle Model

Then add the test items, including the cycle conditions of the European New Automobile Regulations, the US FTP75 operating conditions, and the 0 to 100 km acceleration performance test, and the 80 to 120 km acceleration performance test.

4.3 Co-simulation and Analysis

The simulation was performed separately for the fuzzy torque control module and the torque management model that was not added to the module. Figure 4-5 and Figure 4-6 show the power curves of NEDC operating conditions without fuzzy control and fuzzy control, respectively. Fig. 4-7 and Fig. 4-8 show the power curves of FTP75 without fuzzy control and fuzzy control, respectively.

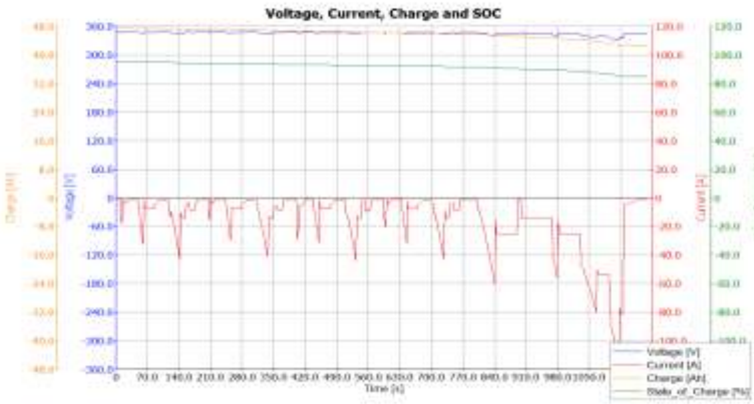

Figure 4-5 Electric quantity curve of NEDC operation without fuzzy control

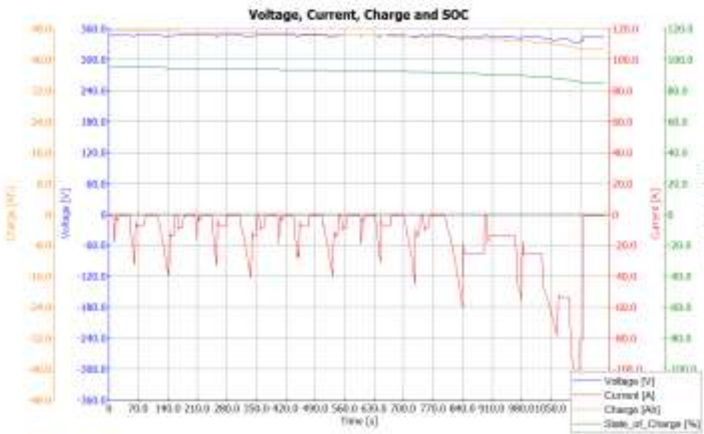

Figure 4-6 Electricity curve of NEDC operating conditions with fuzzy control

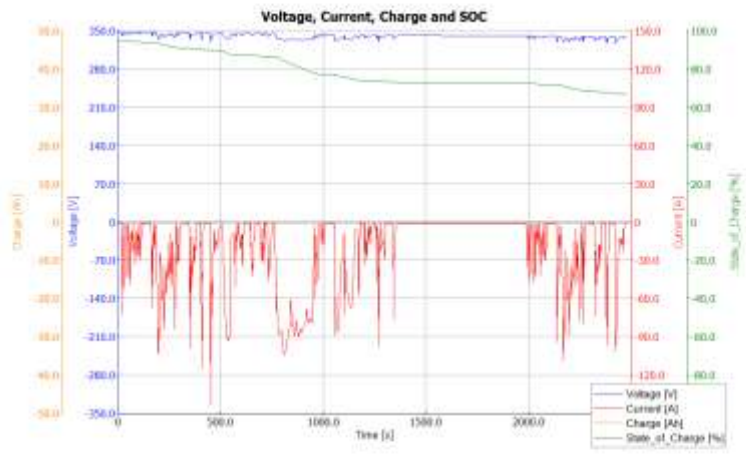

Figure 4-7 Power curve of FTP75 without fuzzy control

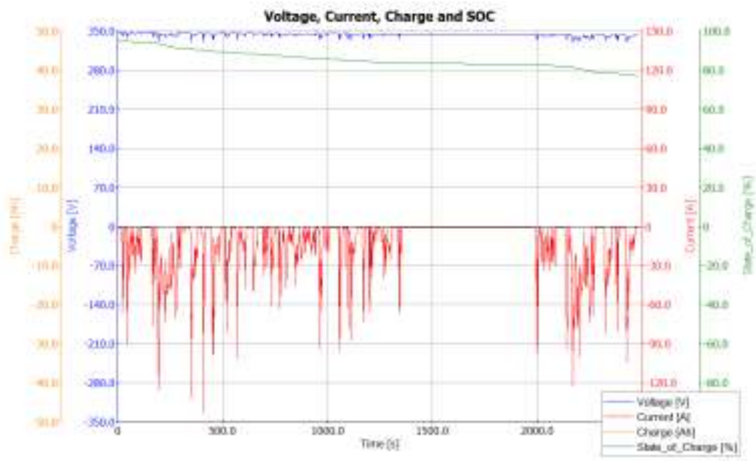

Figure 4-8 Power curve of FTP75 with fuzzy control

The power consumption without fuzzy control and fuzzy control is shown in Table 4-1. The acceleration situation is shown in Table 4-2.

Table 4-1

Operating conditions	Model type	Initial SOC（%）	End SOC（%）	Power consumption percentage（%）	Power consumption（kw·h）
NEDC	No fuzzy control	94.9941	77.1211	17.873	1.743
	Fuzzy control	94.9958	85.0395	9.9563	1.702
FTP75	No fuzzy control	94.9019	66.7884	28.1135	4.749
	Fuzzy control	94.9972	84.7958	10.2014	3.039

Table 4-2

Model type	0-100km/h（s）	80-120km/h（s）
No fuzzy control	11.83	7.45
Fuzzy control	11.83	7.45

From the electric quantity curve and Table 4-1, after the fuzzy control of the output torque curve, the power consumption of 0.041kw·h under NEDC operating conditions is reduced, and the power consumption of 1.71kw·h under FTP 75 conditions is reduced. Effectively improve the economic efficiency of electric vehicles; from the data in Table 4-2, fuzzy control has no significant effect on the acceleration performance of the original electric vehicle.

V. Summary

This paper analyzes the current torque management methods commonly used in electric vehicles, proposes a fuzzy control torque management strategy based on motor output torque curve, establishes a strategy model in Simulink, and builds a complete vehicle model in AVL Cruise, and conducted a joint simulation. Simulation results show that the torque management strategy proposed in this paper can effectively improve the economic efficiency of electric vehicles without changing the acceleration performance of the original vehicle.

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