Research on Acceleration Compensation Strategy of Electric Vehicle Based on Fuzzy Control Theory

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Abstract. Nowadays, the driving technology of electric vehicle is developing rapidly. There are many kinds of methods in driving performance control technology. The paper studies the acceleration performance of electric vehicle. Under the premise of energy management, an acceleration power compensation method by fuzzy control theory based on driver intention recognition is proposed, which can meet the driver's subjective feelings better. It avoids the problem that the pedal opening and power output are single correspondence when the traditional vehicle accelerates. Through the simulation test, this method can significantly improve the performance of acceleration and output torque smoothly in non-emergency acceleration to ensure vehicle comfortable and stable.

1. Introduction
The issue of environmental pollution is currently more and more serious. Under the pressure of environmental problems, more and more people pay attention to the electric vehicles. Various automotive manufacturers are increasing investment in pure electric vehicle. Battery electric vehicle research has become an important direction. Acceleration performance is an important indicator for car evaluating. On the one hand, people hope that vehicles can accelerate smoothly based on people's intention for safety and comfort, on the other hand, people hope that vehicles can speed up in the power demand. Therefore, the judgment by controller is very important to the driver's intention recognition and power output.

This paper presents a method for solving different dynamic response problems of vehicles under different driver intentions. The driver's intent is reflected in the opening of the accelerator pedal. The controller controls the power output through the pedal opening MAP. At the same time, the change rate of the accelerator pedal is judged, and the compensation of the vehicle power is determined by the reasoning of human experience, which Increase the output of power in acceleration to meet the driver's needs.

2. The acceleration compensation strategy
The driver's intention to the car is reflected in the size of the pedal opening and the pedal opening rate, which is very complex. Traditional control methods have limitations that the acceleration pedal and
power output have only a single mapping relationship. This paper takes the electric platform of Hebei University of Engineering as the test object, combined with acceleration pedal opening, acceleration pedal opening rate and battery SOC value to research. When the value of SOC is low, it appropriate to reduce the compensation or no compensation to ensure that the vehicle run farther. When the value of SOC is high, the compensation value can be appropriately increased to ensure the power performance. Therefore, with a variety of input variables, the application of the fuzzy control theory can better reflect the control intention than the classical control theory. It is the first choice of nonlinear control problem without relying on mathematical model.

3. Fuzzy Controller Design
Fuzzy controller is the core of fuzzy reasoning, which structure is shown in Figure 1. The input parameters are pedal change rate, SOC of battery and the accelerator pedal opening degree. The input of fuzzy controller is normalized. The rate of change of acceleration pedal normalized to $K$, which is equal to $\frac{d\theta}{dt}$. $K_1$ and $K_2$ are the upper and lower threshold of the change rate. When the pedal change rate is lower than $K_1$, it is equal to $K_1$, when the pedal change rate is higher than $K_2$, it is equal to $K_2$. The domain of $k$ is $[0, 1]$. 0 indicates that the pedal change rate is below or equal to $k_1$, 1 indicating that the pedal change rate is above or equal to $K_2$. The input of SOC is the battery energy state after normalization, which domain is $[0,1]$. 0 indicates that the SOC value is less than or equal to 20%, and 1 represents the saturation state of the battery. The input of $\theta$ is the accelerator pedal opening after normalization, which domain is $[0,1]$. 0 indicates that the pedal opening is at position of 0% and the 1 represents the maximum opening position of the pedal. $K$ is the proportional parameter after fuzzy inference, which domain is $[0,1]$. $K$ is the proportional factor of compensating power. 0 represents no compensation and 1 represents the maximum compensation.

![Figure 1. Fuzzy controller structure](image)

The selection of membership function has many methods, such as two element comparison sort method, assignment method, fuzzy statistics method, etc [1-2]. It is influenced not only by objective rules but also by subjective factors of designers. Based on the reference of other literatures and the similar control cases [3-4], the Gauss type function is chosen to be applied to input variables and output variables. The value of SOC, pedal opening and pedal change rate have the same Gauss points [5]. $L_1$ represents small, $M_1$ represents medium little, $M_e$ represents medium, $M_b$ represents medium big, $H_i$ represents high. The input and output fuzzy subsets are as follows:

- SOC: $\{L_i, M_e, H_i\}$
- $k$: $\{L_i, M_e, H_i\}$
- $\theta$: $\{L_i, M_e, H_i\}$
- $K$: $\{L_i, M_i, M_e, M_b, H_i\}$

The input and output membership functions are shown in Figure 2-3.

![Figure 2. Input membership function](image)
The conditions for the accelerator pedal compensation are described as follows:

(1) When the value of SOC is low and the pedal opening conversion is not obvious, there is no acceleration power compensation. When the accelerator pedal opening change is large, which means that the driver has a sharp acceleration intention, there is a small amount of compensation appropriately.

(2) When the battery SOC value is high or medium, the compensation focuses on the acceleration pedal changes. When the pedal change is not obvious, there is a small amount of compensation. When the pedal opening and pedal change rate are large, it is considered that the intention of acceleration is obvious, so the power compensation is high.

Table for fuzzy logic rules is shown as Table 1. Fuzzy controller reasoning surface graph is shown as Figure 4.

| k | 0 | K | k | 0 | K |
|---|---|---|---|---|---|
| SOC=Li | SOC=Me | SOC=Hi |
| Li | Li | Li | Li | Li | Li |
| Li | Me | Li | Li | Li | Me |
| Li | Hi | Li | Hi | Li | Me |
| Me | Li | Me | Li | Me | Li |
| Me | Me | Me | Me | Me | Me |
| Me | Hi | Me | Hi | Me | Me |
| Hi | Li | Hi | Hi | Hi | Hi |
| Hi | Me | Hi | Hi | Hi | Hi |

Table 1. The optimization target and weight coefficient

4. Control strategy

The output of power is embodied in the request of the vehicle management System (VMS) for the output torque of the motor controller [6]. The acceleration compensation means that increase an appropriate torque value based on the torque output of the motor, which make the motor speed of the vehicle to the target speed fleetly. This paper uses the method of control input power to motor to change the torque. Electric vehicle power flow is shown in Figure 5.
The battery management system controls the output of the power according to the command of the vehicle controller. $P_{\text{motor}}$ represents the power consumed by the motor. The power consumed by the low voltage load and the high voltage load shall not be distinguished in this article, which recorded as $P_e$. $P_w$ represents the loss of energy in transmission. The power request of the acceleration compensation system based on fuzzy controller is shown in Figure 6. In the absence of compensation, the electric vehicle output the standard request power through the pedal MAP, when the fuzzy controller is involved in the calculation of the parameters $K$, the electric vehicle compensation power is $KP_{\text{con}}$. $P_{\text{con}}$ is the smallest unit of power compensation. In order to better reflect the original intention of energy management, $P$ is set to dynamic variables through the SOC-MAP diagram calculation. $P_{\text{con}}$ is a function mapping of the battery SOC value and the same size as it. When the SOC value of the battery is large, the $P_{\text{con}}$ value is the largest. When the SOC value is less than 25%, the $P_{\text{con}}$ value is the smallest. Therefore, the request for compensation for power:

$$P_{\text{motor1}} = P_{\text{motor}} + KP_{\text{con}}$$

(1)

$P_0$ represents the actual output power of the motor, which is calculated according to the feedback of the motor speed $n$ and the current torque $T$:

$$P_0 = nT / 9550$$

(2)

The actual demand of the vehicle is:

$$P_{\text{re}} = P_{\text{motor1}} + P_e + P_w - P_0$$

(3)

Figure 6. Power request structure based on fuzzy control

5. Simulation results
The simulation model of acceleration compensation of electric vehicle is built by Matlab/Simulink based on the structure of fuzzy control. Pedal input is simulated by the Ramp module in Simulink as shown in Figure 7. The pedal opening is 90% and the slope is the rate of change of the accelerator pedal.

Figure 7. Accelerator pedal simulation
The simulation results are shown in Figure 8-9.

![Figure 8. Torque output of 30% SOC](image1)

![Figure 9. Torque output of 80% SOC](image2)

As can be seen from the Figure 8-9, Acceleration compensation is still a small value even if the pedal is open to 90% when the SOC value is relatively small. A small increase in power compared to the non-compensatory control strategy. When the SOC value is higher, the compensation value of torque increases and the output power increases obviously.

6. Conclusions
On the basis of traditional electric vehicle control theory, in this paper, the acceleration change rate is judged and the battery state is used to realize the compensation of driver's intention recognition for power output. The corresponding simulation model is established based on Simulink. A fuzzy controller is designed in this paper, which is used to realize the dynamic control of multiple nonlinear constraints. The test results show that the control strategy can compensate the torque in the acceleration and can be adjusted dynamically according to the driver's intention. In the application, according to the different types of vehicles and the driver's needs, adjust the SOC-MAP to realize the change of the Pcon, which make the power compensation adjustment more convenient. The model is valuable to the research and application.

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