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Double Fuzzy Logical Control in Hybrid Power Supply Electric Vehicle

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Abstract. The hybrid power supply of fuel cell and super capacitor combines the advantages of high energy density of fuel cell with high power density of super capacitor. Based on the fuzzy logical control strategy, two fuzzy logical controllers are set up to participate in power distribution, and the simulation verification is carried out under the standard working Condition experiment, which effectively reduces the driving energy consumption of pure electric vehicles. This scheme control strategy is simple and easy to engineer.

1. Introduction

Hybrid power supply is combined with the high energy density characteristics of the fuel cell and the high power density characteristics of the super capacitor, which can recover the braking energy of the vehicle under the power distribution scheme of the fuzzy logical control, and give full play to the advantages of the fuel cell and the super capacitor[1] [2].

2. Parameter Matching

Vehicle parameters as shown in table 1:

Table 1. Vehicle parameters

Items	Parameters
Mass of the empty vehicle	1160kg
Mass of the whole vehicle	1750kg
Reduction ratio	7.93
Frontal area	2.4m ²
Coefficient of rolling friction	0.137
Drag coefficient	0.284
Transmission efficiency	0.96



2.1. Motor Parameter Matching

P_1^{MAX} and P_2^{MAX} are obtained based on the maximum climbing degree and the parameter matching of the motor with the maximum driving speed.

1) According to the maximum climbing degree to match the motor power:

$$P_1^{MAX} = \frac{1}{3600\eta_T} (mgf \cdot \cos \alpha_{MAX} + \frac{C_D A V_1^2}{21.15} + mg \cdot \sin \alpha_{MAX}) \cdot V_1 \quad (1)$$

Where P_1^{MAX} indicates vehicles at the 15° power requirements when uphill, η_T indicates that the total efficiency of vehicle power system transmission is 96%, m indicates vehicle quality 1750kg, g indicates that the gravitational acceleration which equals 9.8m/s², α_{MAX} indicates the maximum climbing angle of 20°, C_D indicates that the air resistance coefficient which equals 0.284, A indicates windward area 2.4m², V_1 indicates the speed at which driving on the maximum slope which equals 20km/h, f indicates that the rolling friction coefficient which equals 0.0137

2) According to the maximum driving speed to match the motor power:

$$P_2^{MAX} = \frac{1}{3600\eta_T} (mgf + \frac{C_D A V_{MAX}^2}{21.15}) \cdot V_{MAX} \quad (2)$$

where P_2^{MAX} indicates the power requirements of the vehicle when driving at maximum speed 120km/h, V_{MAX} indicates the maximum speed which equals 120km/h.

The maximum power requirement of the motor P_E meets the following formula:

$$P_E \geq MAX(P_1^{MAX}, P_2^{MAX}) \quad (3)$$

According to the formula (1) formula (2) we could calculate the $P_1^{MAX}=35.30\text{kw}$, $P_2^{MAX}=24.27\text{kw}$. By formula (3) know P_E equals the maximum value in P_1^{MAX} and P_2^{MAX} . In view of the normal operation of the vehicle will encounter temperature and specific road conditions and other factors of the affection. Therefore, the peak power of the motor should be greater than the calculated value, take $P_E=40\text{kw}$ to ensure the normal driving of the vehicle [3].

2.2. Fuel Cell Parameter Matching

In this paper, the parameters of the fuel cell are matched according to the maximum mileage of the vehicle.

$$P_{FC} = \frac{1}{3600\eta_T} (mgf + \frac{C_D A V_2^2}{21.15}) V_2 \quad (4)$$

In the formula:

P_{FC} is the power that fuel cells need to provide when cruising at V_2 speed of 60km/h, V_2 is the vehicle's cruising speed which equals 60km/h.

Calculate the capacity of the fuel cell based on the maximum mileage of the vehicle:

$$W = \frac{S P_{FC}}{V_2} \quad (5)$$

where S indicates the maximum mileage to which equals 800km, W indicates the energy required for the vehicle to travel the maximum mileage.

After calculating get the $P_{FC}=6.09\text{kw}$, the energy required when the vehicle travels at a distance of 800km $W=81.2\text{kw}\cdot\text{h}$.

3. Power Distribution Scheme

As shown in Figure 1, fuzzy logical control, as a new control strategy, can imitate the precise input blur processing, inference and the output of reasonable results through the solution fuzziness, and has a greater advantage over the logical threshold control in terms of reliability[4]-[6].

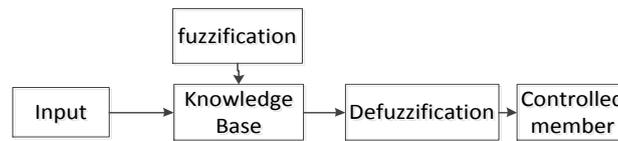


Figure 1. Process of fuzzy logical control

3.1. Selection of Control Quantities

As shown in Figure 2. When driving normally, the fuzzy logical controller FLC1 is involved in the work, with the input of LoadSignal, the charge state of the fuel cell (FC_SOC) and the Charge State (UC_SOC) of the super capacitor, and the output is the power demand for the fuel cell (FC_req) And the power demand for supercapacitors (UC_req). When the vehicle is in a braking state, the fuzzy logical controller FLC2 is involved in the input of the braking pressure and the Charge State (UC_SOC) of the supercapacitor, and the output is the power requirement for the supercapacitor (UC_req).

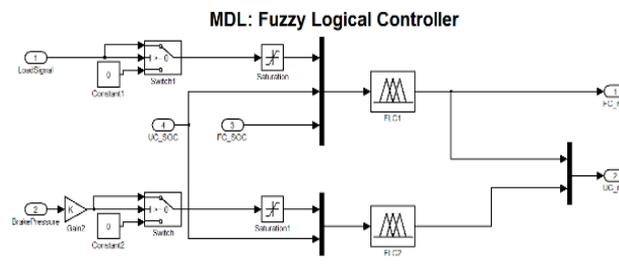
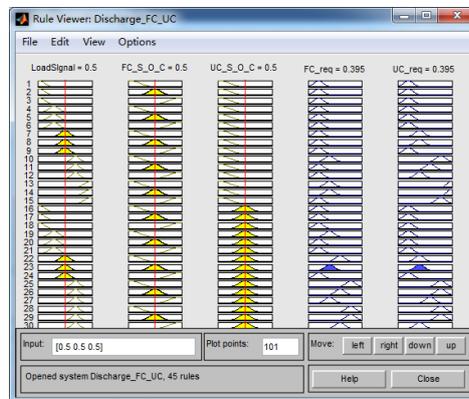
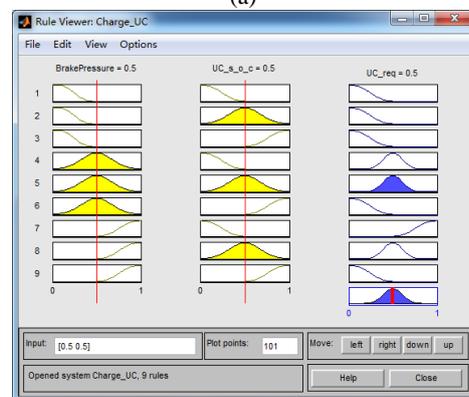


Figure 2. Power allocation strategy



(a)



(b)

Figure 3. Rule watcher when driving normally and braking

3.2. Building of Knowledge Base

As shown in Figure 3 when the electric vehicle is in normal driving, the LoadSignal is at a low or medium level, and when the FC_SOC is large, the fuel cell's separate output power meets the power demand of the vehicle, and when the LoadSignal of the electric vehicle is at a higher level, the individual output of the fuel cell is no longer sufficient to meet the power demand of the vehicle, will be output by supercapacitors and fuel cells.at the same time to meet vehicle power requirements.

When the electric vehicle is in the braking state and the input BrakePressure and UC_SOC is small, the output UC_req is larger; When the UC_SOC is large, the output UC_req is smaller.

3.3. Defuzzification Method

In this paper, the center of gravity method is used as the solution defuzzification method, that is, by calculating the center of gravity of the graph formed by the membership function and the axis as the precise output, the calculation method is as follows:

$$V_0 = \frac{\int V \mu_v(v) dv}{\int \mu_v(v) dv} \quad (6)$$

4. Verification of Hybrid Power Supply

Figure 4 is a comparison diagram of the speed/acceleration - time between the single-power ev and the hybrid power source ev. It can be seen that from 0 to 100km/h, the acceleration time of single power source electric vehicles is 13.76 seconds, while that of pure electric vehicles with hybrid power source is 12.95 seconds.

Figure 5 is a single power supply of pure electric vehicle climbing capacity and composite power supply pure electric vehicle climbing-speed comparison chart, you can see that the composite power supply in the same slope when driving, faster; at the same speed, composite power electric vehicle is afraid of greater slope. At 60km/h, the climbing degree of single power source electric vehicles is 14.23%, while that of hybrid power source pure electric vehicles is 23.39%.

To verify the vehicle's cruising ability, the vehicle is tested in a fixed speed, cruising at 60km/h speed, and the SOC range for the fuel cell is set at 90%~10% when cruising. According to the figure 5 we can know 17.79% of the fuel cell's SOC is left when the vehicle reaches 800km in travel distance.

As shown in figure 7,in WLTP conditions under the fuzzy logical controlled power distribution measurement, the fuel cell always discharges at a small current, while the supercapacitor carries out a high current discharge according to the power demand of the vehicle, receiving the braking current during braking to enhance the vehicle's life capacity.

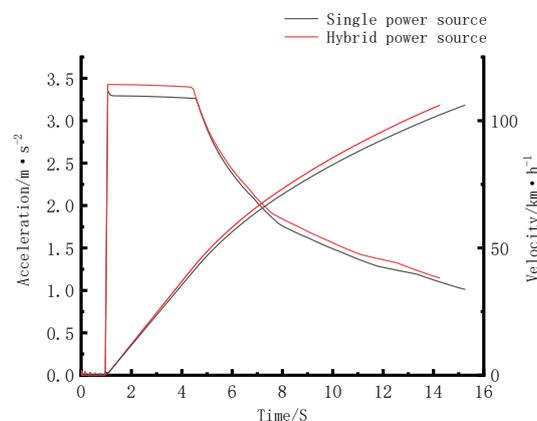


Figure 4. Comparison of velocity/acceleration - time

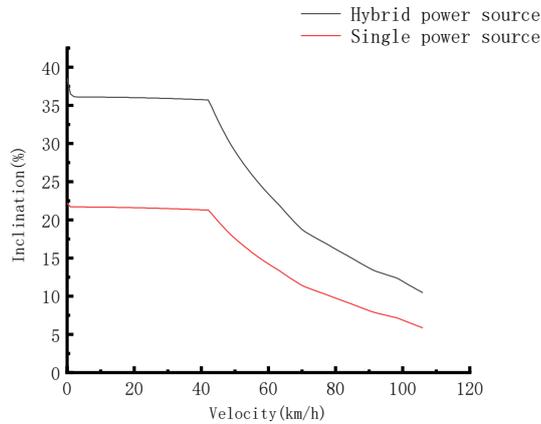


Figure 5. Slope-speed comparison chart

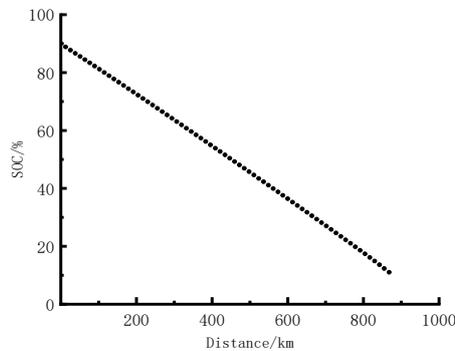


Figure 6. Change of SOC with driving distance

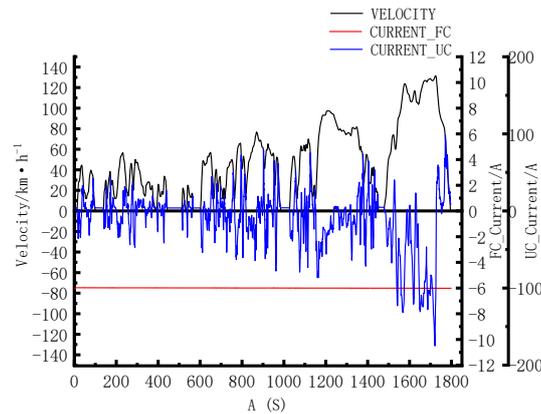


Figure 7. Current flow under WLTP conditions

5. Conclusions

In this paper, a hybrid power supply composed of fuel cell and super capacitor is studied, which improves the recovery efficiency of braking energy under the power distribution strategy of double fuzzy control, avoids the too frequent charging and discharging of the battery, and realizes the long mileage cruising and extends the service life of the cell. At the same time improve the climbing ability and acceleration ability of electric vehicles. To a certain extent, the problem of insufficient endurance and service life of pure electric vehicles is improved.

Acknowledgments

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