# Research on Vehicle Hybrid Energy Storage Based on Fuzzy Control

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## Abstract

In this paper, lithium iron phosphate battery is used as the main energy source and super capacitor is used as auxiliary energy to form mixed energy storage. The bidirectional flow of energy is realized by bidirectional half-bridge DC/DC converter. The fuzzy logic control method is used to control the energy management of the vehicle hybrid energy storage system. The corresponding fuzzy controller is designed in MATLAB/Simulink environment, and then the hybrid hybrid energy storage is simulated under NDES cycle condition to verify the effectiveness of the control strategy.

## Keywords

Electric vehicle, lithium battery, super capacitor, hybrid energy storage, fuzzy control, energy management.

## 1. Introduction

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At this stage, with the improvement of people's living standards, cars have become an indispensable means of transportation for daily life, bringing great convenience to people's travel.But traditional cars have to face the problem of oil fuel shortage and air pollution. The pure electric vehicle uses the battery as the power source, and does not generate exhaust gas during the driving process, so there is no environmental pollution problem, and the energy utilization rate is higher.The battery has a high energy density but a low power density[1]. The charge and discharge current is limited and cannot withstand high power requirements.In the pure electric vehicle, there are various problems, such as sudden acceleration, climbing, and sudden braking.This is extremely demanding on the power system. Obviously, a single power supply cannot meet the driving requirements of complex road conditions.At this stage, many colleges and car companies have invested in research on hybrid energy storage electric vehicles[2].The addition of super capacitors can solve the problem that the current pure electric vehicles have poor endurance and cannot cope with frequent start and stop.The supercapacitor has high power density, small energy density, long cycle life and large working current. It can instantaneously release electric energy or absorb electric energy under different working conditions, avoiding damage to the battery due to large current and prolonging the life of the battery.

In order to solve the problems caused by the above single energy, this paper uses two-way half-bridge DC-DC converter and fuzzy logic control method to control the energy management of the vehicle hybrid energy storage system. Develop a detailed fuzzy control strategy to achieve the purpose of energy recovery and protection of lithium batteries. Figure 1 is a block diagram of the electric vehicle hybrid energy storage system.

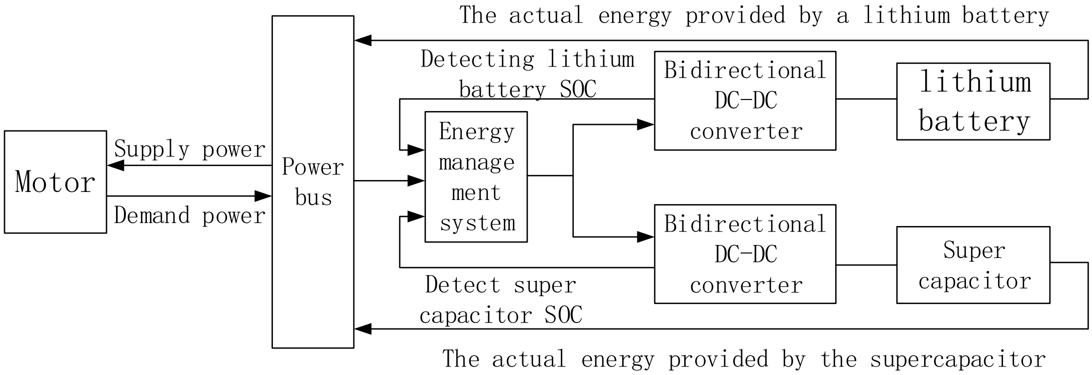


Fig .1 A block diagram of the electric vehicle hybrid energy storage system

## 2. Organization of the Text

### 2.1 Principle of mixed energy storage

The power distribution mode of energy storage electric vehicles under different operating conditions is shown in Figure 2. The main output of the lithium iron phosphate battery does not exceed the maximum steady state driving power, and the super capacitor output exceeds the peak power of the maximum average power of the lithium iron phosphate battery, compensating for the peak portion of the output power of the lithium iron phosphate battery. When the required power is less than zero, the supercapacitor and the lithium battery perform energy absorption to different degrees. According to the operating conditions of electric vehicles, the power supply modes of hybrid energy storage include the following four types: lithium iron phosphate battery power supply mode, separate super capacitor power supply mode, lithium iron phosphate battery and super capacitor hybrid power supply mode, and recovery braking energy mode[3].

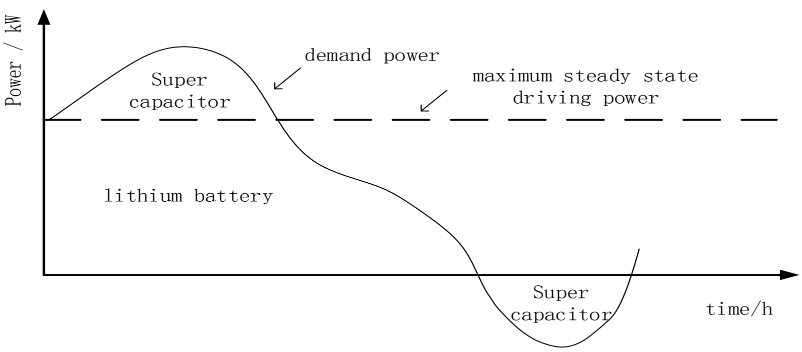


Fig .2 Hybrid energy storage working principle

### 2.2 Design of bidirectional DC/DC converter circuit

The lithium iron phosphate battery and the super capacitor are respectively connected to the busbar structure after being connected in series with the bidirectional DC/DC converter. Compared with other structures, the structure can flexibly adjust the input and output voltages of the mixed energy storage to improve the stability of the DC bus voltage. While saving energy, it also extends the cruising range. Therefore, in order to give full play to the advantages of hybrid energy storage, this design uses a parallel DC-DC converter structure.

The bidirectional half-bridge DC-DC converter is widely used in electric vehicles due to its small voltage and current stress. Compared with other converters, the bidirectional half-bridge DC-DC converter has the following advantages: the control circuit is relatively simple; the switching element and the diode are subjected to the minimum voltage and current; and the transmission of energy by the inductor can save a large capacity transfer capacitor; The device's conduction loss is minimal, making the converter more efficient. Therefore, the design of this question uses a bidirectional half-bridge DC-DC converter topology.

When the bidirectional half-bridge DC-DC converter operates in Boost mode:

$$L_{boost} \geq \frac{V_{sc} D_1 (1-D_1)}{2 I_{o\min} f} \tag{1}$$

When the bidirectional half-bridge DC-DC converter operates in Buck mode:

$$L_{buck} \geq \frac{V_{dc} D_2 (1-D_2)}{2 I_{o\min} f} \tag{2}$$

In the formula, $V_{sc}$ is the terminal voltage of the battery pack and $V_{dc}$ is the DC bus voltage. $D_1, D_2$ are the duty ratio of the switch tube $S_1$ and the switch tube $S_2$ respectively. $f$ is the switching frequency and $I_{o\min}$ is the critical continuous load current.

The selection of the filter capacitor in the bidirectional half-bridge DC-DC converter should minimize the DC ripple, meet the requirements of the ripple coefficient, and consider the quality, volume and price of the capacitor. The capacitance is designed according to the magnitude of the output voltage DC ripple and the voltage transient ripple index.

When the bidirectional half-bridge DC-DC converter operates in Boost mode, the capacitance on the DC bus side is $C_{dc}$, the energy of charge and discharge is $\Delta Q$, and the resulting voltage ripple coefficient is $\Delta V_{dc}$,it can be expressed by the following formula:

$$\Delta V_{dc} = \frac{\Delta Q}{C_{dc}} = \frac{I_{dc} D_1 T_S}{C_{dc}} = \frac{P_0}{V_{dc} C_{dc}} D_1 T_s \tag{3}$$

In the formula, the load current on the DC bus side is $I_{dc}$, the rated power of the converter is $P_0$, the switching period of the switching tube is $T_s$ and the required ripple voltage is $\Delta V_{dc}$.

$$C_{dc} \geq \frac{P_0}{V_{dc} \Delta V_{dc}} D_1 T_s \tag{4}$$

According to the requirements of the system, the voltage ripple coefficient of the DC bus should not exceed 1%. The value of the filter capacitor $C_{dc}$ can be determined by the following formula: 0.0032F.

When the bidirectional half-bridge DC-DC converter operates in Buck mode, the amount of change in the inductor current is:

$$\Delta i_L = \frac{V_{sc} T_s}{L} D_2 (1-D_2) \tag{5}$$

In the formula, $\Delta i_L$ is equal to the amount of change in the capacitor current $\Delta i_C$ and the amount of change in the load current $\Delta i_o$.If the charging is completed within（$T_{ON} + T_{OFF}$）$/2 = T/2$, the average charging current of the filter capacitor is:

$$\Delta I_C = \frac{\Delta i_C}{4} = \frac{\Delta i_L}{4} = \frac{V_{sc} T_s}{4L} D_2 (1-D_2) \tag{6}$$

The peak ripple voltage of the filter capacitor is:

$$\Delta V_{sc} = \frac{1}{C_{sc}} \int_0^{\frac{T}{2}} \Delta I_C dt = \frac{1}{C_{sc}} \frac{V_{sc} T_s}{4L} D_2 (1\text{-}\mathrm{D}_2) \frac{T_s}{2} = \frac{V_{sc} D_2 (1-D_2)}{8 L C_{sc} f^2} \tag{7}$$

From the above formula:

$$C_{sc} = \frac{V_{sc}}{8L\Delta V_{sc} f^2} D_2(1 - D_2) \tag{8}$$

According to the requirement that the maximum writing coefficient of the system charging voltage should not exceed 1%, the value of the filter capacitor is:

$$C_{sc} = \frac{V_{sc} D_2 (1 - D_2)}{8L\Delta V_{sc} f^2} = 7.5\text{e}^{-5}\text{F} \tag{9}$$

Therefore, the filter capacitor on the lithium battery side is selected to be $7.5e^{-5}\text{F}$ .

## 3. Fuzzy control strategy

Because the fuzzy control strategy adjusts the power output ratio of the two energy storage units in the hybrid energy storage system to be related to the actual SOC, the power distribution process must also take into account factors such as extending the service life of the energy storage unit and ensuring the power supply performance of the composite power supply. It is necessary to limit the working range of the two energy storage unit SOCs.

Since the power required by the hybrid power supply electric vehicle is provided by the battery and the super capacitor in accordance with the power output ratio given by the energy management system, namely:

$$P_{\text{req}} = P_{\text{sc}} + P_{\text{bat}} \tag{10}$$

In summary, this paper takes the demand power $P_{req}$ of the electric vehicle, the state of charge $SOC_{\text{bat}}$ of the lithium iron phosphate battery, the state of charge of the super capacitor as the input quantity $SOC_{\text{sc}}$, and $K_{bat}$ as the output factor as the output variable.

The fuzzy set is generally: NB (Negative Big) ,NM (Negative Medium), NS(Negative Small),PB (Postive Big) , PM (Postive Medium) ,PS(Postive Small), Z (Almost Zero) .

Part of the fuzzy control strategy is as follows:

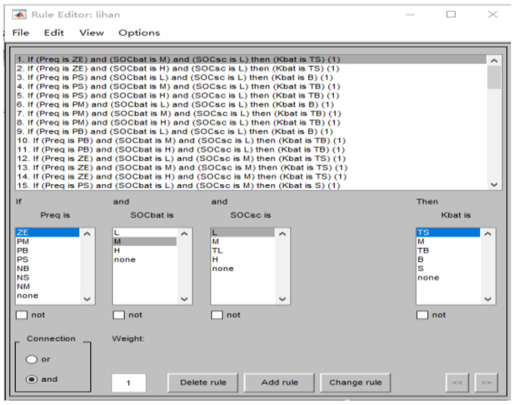


Fig .3 Fuzzy control strategy

## 4. Simulation results

The simulation results are shown in the figure .4 below.

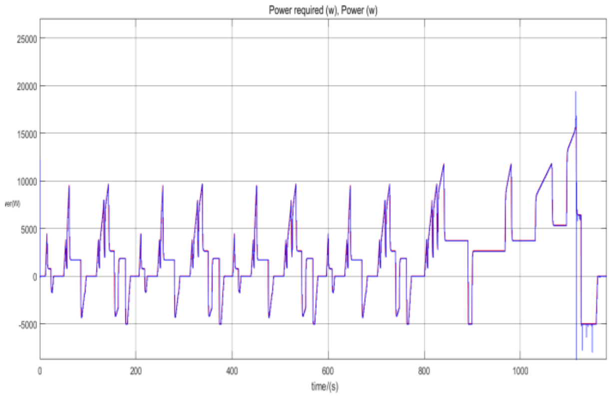


Fig .4 Fuzzy control distribution power

## 5. Summary

Under NEDC conditions, the vehicle demand power curve is consistent with the output power curve of the hybrid energy storage system electric vehicle, which also verifies the correctness and feasibility of the fuzzy control strategy.

## References

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