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Research and simulation of energy control strategy for pure electric vehicle based on advisor

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Abstract. This paper is based on the simulink and advisor2002 simulation software, aiming at the energy control strategy of pure electric vehicle whose energy storage system is composed of batteries and ultracapacitors in parallel. In order to improve the efficiency of braking energy recovery, a hybrid energy system model was built and a fuzzy control based energy allocation strategy was established. The hybrid energy system can reasonably distribute the energy output ratio of batteries and ultracapacitors, and improve the system performance.

1. Introduction

Electric vehicles have the advantages of zero emission, high energy efficiency, and low noise and so on. Under the current situation of energy crisis and environmental pollution, people pay attention to them. Traditional electric vehicles use a single battery as energy, which has the disadvantages of low energy density, short cycle life and high cost. As the sole power source of electric vehicles, battery has great limitations. The ultra-capacitor has the characteristics of high power density, long cycle life, high charge and discharge efficiency. It is not suitable for electric vehicles. Combining the advantages and disadvantages of battery and super capacitor, the hybrid energy composed of battery and ultra-capacitor has excellent charging and discharging performance and braking energy recovery performance, reduces the high current and high power output of battery, prolongs the life of battery, and makes up for each other [1].

The research on hybrid electric vehicle (HEV) with hybrid power supply is more in-depth in the world, and has been put into use in some types of vehicles. However, the research on the energy distribution of electric vehicles needs to be improved. This paper focuses on the energy management strategy of electric vehicles.

2. Selection of structure and control strategies for hybrid power system

2.1. Structure of the hybrid power system

Based on the model of single battery, super capacitor and pure electric vehicle in advisor 2002 software, this paper establishes a new hybrid energy module to replace the original energy storage system module, and establishes a hybrid energy electric vehicle. As shown in the Figure.1, a semi-active hybrid energy structure is adopted, in which the battery is directly connected to the load and the supercapacitor is connected to the load through a bi-directional DC/DC converter which is shown in Fig.2. By adjusting



the DC/DC converter, the input and output currents of the supercapacitor are actively controlled so that the supercapacitor provides instantaneous peak power and the battery provides average power [2].

$$P_{\text{req}} = P_{\text{sc}} + P_{\text{bat}} \quad (1)$$

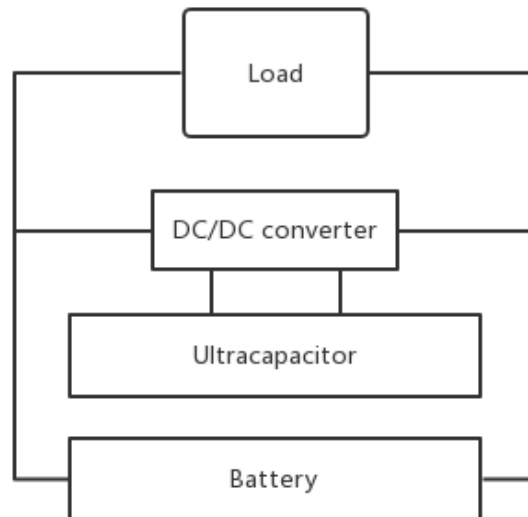


Figure 1. Semi-active control structure

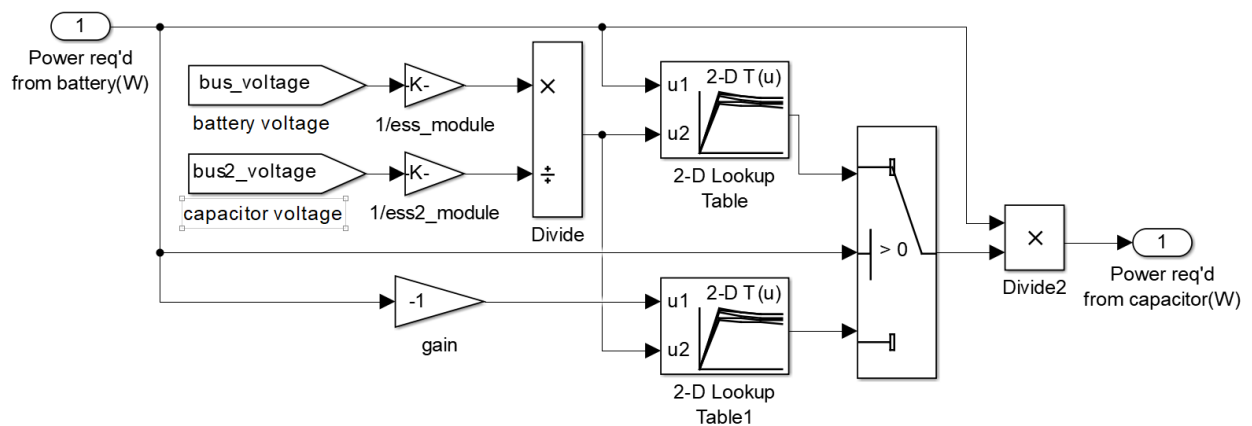


Figure 2. Modeling of DC/DC converter

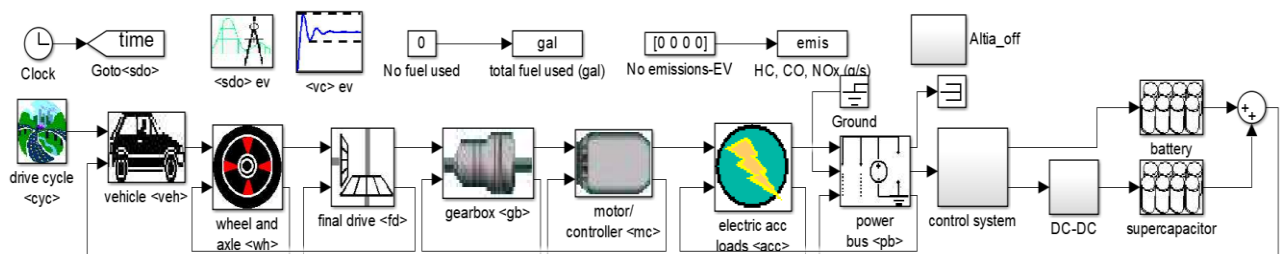


Figure 3. Vehicle system structure

2.2. Control strategy analysis and modeling

At present, the commonly used control strategies are logic threshold control strategy and fuzzy control strategy. This article chooses fuzzy control to control hybrid energy [3].

In this paper, fuzzy control strategy is used to decide the output power ratio of supercapacitors and batteries according to P_{req} (one percent of absolute value of the demand power of the motor), SOC_{bat} (the SOC of the battery) and SOC_{sc} (the SOC of supercapacitor) under the principle that the battery provides the average demand power of the motor and the supercapacitor provides instantaneous high power. K_{sc} (power output ratio of supercapacitor) is determined by these three decisions through fuzzy control.

According to the actual situation, the actual ranges and the fuzzy levels of inputs and output are decided, shown in TABLE I.

VS(very small) S(small) M(middle) B(big) VB(very big) VL(very low) L(low) M(middle) H(very high)

$$P_{req} = |P_{moto}|/100 \quad (2)$$

$$K_{sc} = P_{sc} / (P_{sc} + P_{bat}) \quad (3)$$

Table 1. The fuzzy range of input and output variables

Number	Input and output variables	Actual range	Control range	Level
1	P_{req}	-100-100	0-1	VS,S,M,B,VB
2	SOC_{bat}	0-1	0-1	L,M,H
3	SOC_{sc}	0-1	0-1	VL,L,M,H
4	K_{sc}	0-1	0-1	VS,S,M,B,VB

2.3. Specific contents of control strategy

The membership functions are triangular, trapezoidal, Gaussian and so on. We choose Gaussian and bilateral Gaussian membership functions. As shown in Fig.4, graph a is P_{req} (demand power factor) membership function, graph B is SOC_{bat} membership function, graph C is SOC_{sc} membership function, and graph D is K_{sc} (output ratio of ultracapacitor) membership function.

When the demand power P_{req} is less than 10 kw, the membership function value of P_{req} is 1 for the VS set, then the power is very small, and the supercapacitor does not act, so as to save the energy stored in the supercapacitor to release when the power demand P_{req} is large; when the power demand P_{req} is between 25 kw and 45 kw, P_{req} belongs to the S set; When P_{req} is above 90, it is defined as 1, so as not to damage the device by excessive power.

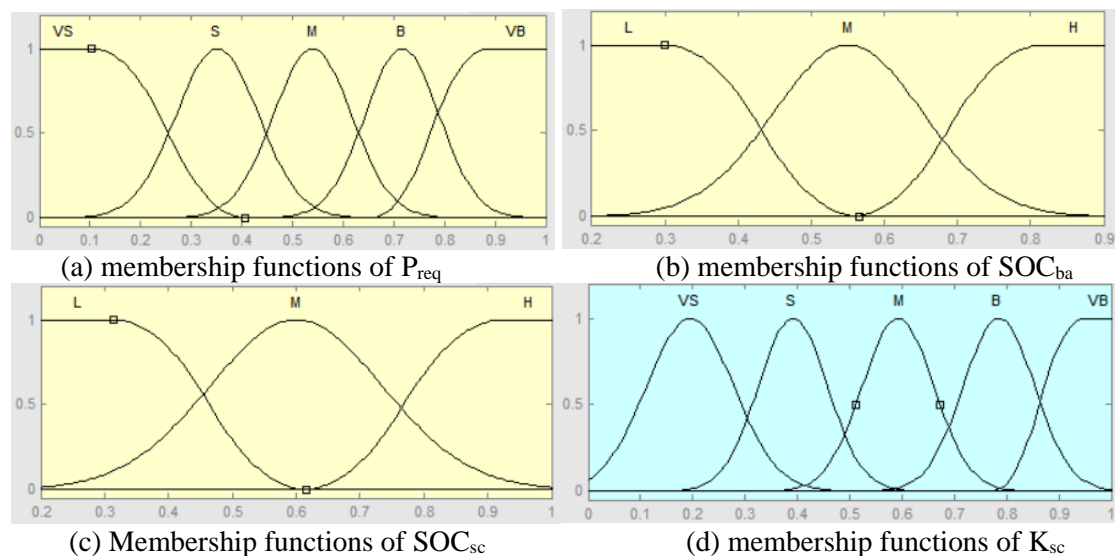


Figure 4. Membership functions of input and output variables

The working range of the battery SOC_{bat} ranges from 0.1 to 0.9. When SOC_{bat} is lower than 0.3, the membership function value of SOC_{bat} for L is 1 to avoid excessive discharge; when SOC_{bat} is higher than 0.8, the membership function value of B is 1 to avoid excessive charge.

Based on the characteristics of hybrid energy and the requirements of system operation, fuzzy rules are formulated. According to the SOC of hybrid energy, the supercapacitor provides the main power except for the VB load mode. When the SOC grade of the battery is lower than the super-capacitor, the super-capacitor assumes the main power output. When the SOC grade of the battery is higher than or equal to the battery, the super-capacitor assumes the main power output [4].

In braking mode, when SOC_{sc} is large, the batteries bear most of the braking energy, and in other cases, the supercapacitors bear most of the braking energy.

As shown in the picture, Fuzzy inference uses membership function and fuzzy rules to derive fuzzy linguistic values of output. Fuzzy control rules are established according to different states of composite energy.

Table 2. Fuzzy rules of the mode of drive

K_{sc}	SOC_{sc}			
	L		M	H
	L	VS	VS	S
	M	VS	VS	VS
SOC_{bat}	H		VS	S
	Preq=VS			
K_{sc}	SOC_{sc}			
	L		M	H
	L	VS	VS	S
	M	VS	VS	VS
SOC_{bat}	H		VS	S
	Preq=VS			
K_{sc}	SOC_{sc}			
	L		M	H
	L	VS	VS	S
	M	VS	VS	VS
SOC_{bat}	H		VS	S
	Preq=VS			
K_{sc}	SOC_{sc}			
	L		M	H
	L	VS	VS	S
	M	VS	VS	VS
SOC_{bat}	H		VS	S
	Preq=VS			
K_{sc}	SOC_{sc}			
	L		M	H
	L	VS	VS	S
	M	VS	VS	VS
SOC_{bat}	H		VS	S
	Preq=VS			

Table 3. Fuzzy rules of the mode of break

		K_{sc}		SOC_{sc}		
			VL	L	M	H
SOC_{bat}	L		VS	VS	S	
	M		VS	VS	VS	
	H		VS	VS	S	
		Preq=VS				
		K_{sc}		SOC_{sc}		
			VL	L	M	H
SOC_{bat}	L		VS	VS	S	
	M		VS	VS	VS	
	H		VS	VS	S	
		Preq=VS				
		K_{sc}		SOC_{sc}		
			VL	L	M	H
SOC_{bat}	L		VS	VS	S	
	M		VS	VS	VS	
	H		VS	VS	S	
		Preq=VS				

3. Simulation

In order to allocate the output of ultra-capacitor and battery reasonably, the above control strategy is adopted. The system parameters are as follows: 26 batteries are connected in series, the maximum voltage of the monomer is 16.5v, and the minimum voltage is 9.5v. The 99 supercapacitors are connected in series with two sets, of which the single supercapacitor has a maximum voltage of 2.5V [5].

3.1. Results of driving test

Choosing CYC_1015 working condition, the single battery electric vehicle and the hybrid power system electric vehicle are simulated and tested. Simulation conditions and hybrid energy test results are shown in fig.

It can be seen from the diagram that the difference between the battery in the single energy system and the composite energy system, the maximum current, maximum power, current change rate, power change rate of the battery in the composite energy system have been significantly reduced to protect the battery performance.

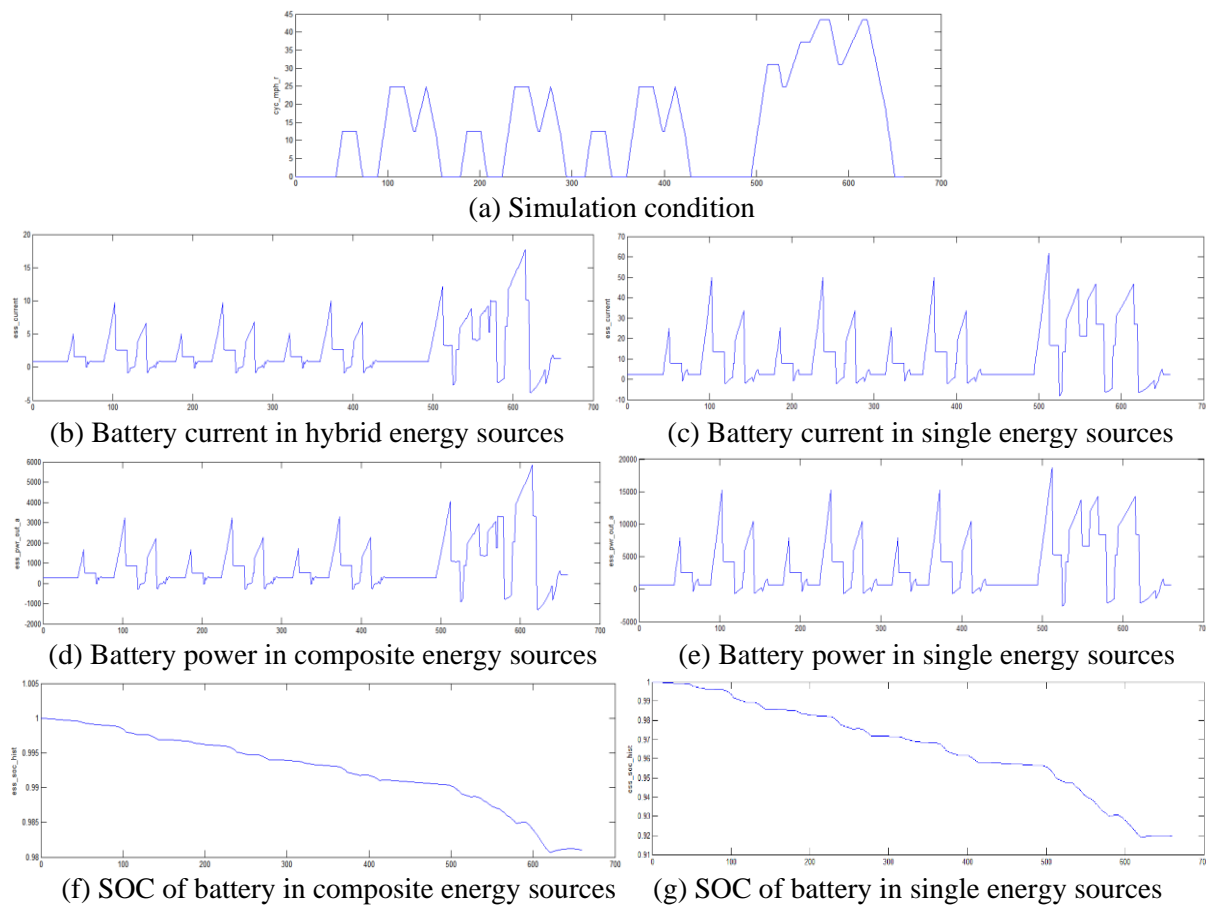


Figure 5. Simulation results of hybrid energy system

3.2. Results of efficiency test

The efficiency and power consumption of two kinds of energy under the same working condition can be calculated by software data, as shown in the table.

In charge, discharge, storage and cycle efficiency, the efficiency of the composite energy system is higher than that of the single energy system. Energy efficiency increased by 3% to 9% in all aspects. The electricity consumption is reduced by 23%.

Table 4. Energy efficiency.

Energy type	discharge eff	recharge eff	storage eff	round-trip eff	power consumption
Single energy	96%	87.35%	83.86%	83.34%	3040KJ
Hybrid energy	99.33%	89.22%	88.63%	89.65%	2260KJ

3.3. Results of acceleration test

Vehicles of the two energy systems were tested for acceleration, fixed distance and maximum speed from 0 to 80 mph to determine which energy system had better performance. The data for accelerated testing are shown in the figure.

Table 5. Results of acceleration test.

Energy type	Time in 0-60mph	Time in 40-60mph	Time in 0-80mph	Diatance in 5s	Time in 0.25 miles	Maximum speed
Single energy	16.4s	9.9s	31.2s	96.3	20s	81.6mph
Hybrid energy	6.6s	2.7s	12.3s	126	15.2s	96.8mph

It can be seen from the data that the acceleration time of the hybrid energy system vehicles is more than 50% less than that of the single energy system vehicles. The maximum speed has increased by 15.7%. Vehicles with composite energy system can save more than 20% of power consumption in the same working condition, increase more than 15% of driving mileage in the same driving time, and reduce more than 18% of driving time in the same driving distance.

4. Conclusion

In this paper, the hybrid energy composed of parallel storage battery and supercapacitor is used as the sole energy source of electric vehicle. Fuzzy logic control is used to control the energy system and distribute the input and output, summarized as the followings.

1) Due to the shortcomings of the battery itself, the battery can adapt to the impact of different working conditions by relying on the characteristics of supercapacitor and Bidirectional DC-DC converter. Therefore, the energy management and control strategy of composite energy sources is proposed.

2) The simulation verifies the efficiency of the control strategy. When the controller detects the change of power demand, the output ratio of the supercapacitor and the battery is changed by fuzzy control, which makes the system in an optimal state of energy release and recovery, and protects the battery from damage.

3) Composite energy improves vehicle system performance, including increased speed, acceleration, reduced fuel consumption, and so on.

4) Compared with logic threshold control strategy, fuzzy logic control does not need to establish an accurate mathematical model of the controlled object, so it makes the control mechanism and strategy easy to accept and understand, design simple, easy to apply, and improves the efficiency of charging, discharging, storage, and cycling of the energy system in the control.

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