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Research on the General Arrangement of New Energy in Automobiles Based on Fuzzy Decision

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In order to study general arrangement design of new energy for automotive, the backward simulation method is used to build a vehicle simulation model on Matlab software platform, besides; the control strategy of energy source system constituted by fuel cells—batteries is prepared. With an economical type hatchback sedan as a prototype, the simulation software is used to carry out simulation analysis and parameter matching on the power system of the fuel cell-battery hybrid electric vehicle. Specific conditions are set for simulation research. The simulation results show that power performance of the fuel cell hybrid electric vehicle using the fuzzy control strategy can fully satisfy the power strategy established and reduce the hydrogen consumption. Therefore, the new energy for automotive based on fuzzy decision can improve the efficiency of vehicle fuel and minimize emissions.

1. Introduction

The rapid development of science and technology speeds up use frequency and update speed of automobiles (Zhang et al., 2015). Especially since the twenty-first century, cars not only bring people convenient, fast and comfortable modern life, but also bring more and more problems, such as, increasingly serious environmental pollution and potential energy crisis (Mardani et al., 2016; Carvalho et al., 2016). Environment and energy are the necessary conditions for sustainable development (Sabri et al., 2016). With the development and progress of society, yield and inventory of traditional internal combustion engine automobiles mainly using gasoline and diesel are increasing (Zeng et al., 2014), which brings environmental pollution and energy shortage into a vicious cycle (Bradley et al., 2014). On one hand, automobile exhaust emissions have become an important source of pollution in the global environment (Ciabattoni et al., 2015); on the other hand, automobiles consume a large amount of oil and gas resources (Hartani and Merah, 2017). Since 2011, the annual consumption of gasoline and diesel used by automobiles has accounted for about half of the total consumption of gasoline and diesel in China, while annual consumption of petroleum consumed by automobiles accounts for about 1/3 of petroleum consumption in China (Amini et al., 2015, Panday and Bansal, 2014). According to estimate of the authority, the proven oil reserves on the earth will be exhausted in 50 years, for which searching for new energy has become the only way for the development of human society (Syahputra, 2013). In recent years, climate deterioration and greenhouse effect have attracted people's attention. Automobile exhaust emission is one of the most important culprits causing bad weather, which has attracted the attention of governments all over the world. Therefore, it is very important to improve the fuel economy and reduce the pollution of automobile exhaust. Hybrid technology provides a feasible and important breakthrough method to solve this problem. In general, a hybrid vehicle means that it has two or more power sources. Usually one of them is an internal combustion engine or a fuel cell. One or more of them are energy storage devices, batteries, supercapacitors, flywheels, or accumulators, which act as energy buffers. At present, most research institutes and automobile companies are studying hybrid electric vehicles. According to statistics, more than 90% of the auto companies are focusing on hybrid electric vehicles. Electric hybrid vehicles have been widely recognized in the light vehicle market.

However, there has not been much attempt in the field of heavy vehicles. So far, almost all car companies are developing, producing and selling hybrid electric cars or light trucks. Due to the conversion efficiency and the

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low power density of electric motors and batteries, the fuel economy increases only a few percent of its potential. Hydraulic hybrid vehicles completely overcome these limitations as a completely new hybrid vehicle technology. Instead of storing the recovered energy in the battery, the hydraulic hybrid vehicle stores the recovered braking energy in the form of high-pressure hydraulic energy in a compressed nitrogen accumulator. In this way, due to the characteristics of the accumulator itself, the hydraulic hybrid vehicle has a very high efficiency and a great power density compared with the electric hybrid vehicle in terms of recovering the braking energy. The hybrid system creates the problem of how to distribute and coordinate energy between the main power source and the auxiliary power source. At present, a large number of articles on energy management strategies for hybrid vehicles have been introduced. Control strategy is the core of hybrid vehicles to improve fuel economy. The energy density of hydraulic accumulators is relatively low. The problem of optimal control needs to be considered. By controlling the power distribution between the vehicle's engine and the auxiliary power source, fuel economy is increased, and emissions are reduced. Under an effective energy management strategy model, the power distribution between two or more power sources is determined. Its fuel economy is improved. In the past twenty years, hybrid energy management system has been a hot spot in the field of research. During this period, a large number of energy management strategies were developed. They are used in hybrid vehicle drive mode control, in order to determine the energy allocation scheme for hybrid power systems. Most of these knowledge programs are based on mathematical models, which are developed through simulation or expertise of engineers. At present, power distribution and energy allocation have been the most popular applications of optimal control theory, including rule-controlled linear programming, optimal control and dynamic programming. In recent years, a variety of intelligent system control methods, such as neural networks, fuzzy logic, genetic algorithms, have been applied to the control strategy of hydraulic hybrid vehicles. Research shows that driving conditions can strongly affect vehicle fuel economy and emissions. Based on the energy management strategy, the magnitude of the vehicle load and the range of efficient engine operation are taken into account. By using fuzzy logic technology, heuristic rules are used to make the engine run in an efficient range. There are many rules based energy management control strategies. On the basis of the control strategy, the joint information fuzzy logic controller is further studied, in order to strengthen the dynamic performance of the vehicle and improve fuel economy.

Dynamic programming algorithm is an optimization method for solving transient or multilevel problems. Dynamic programming is to find optimal decisions from the drive loop rather than from the current optimization point, so that the optimal decision variables can be found throughout the cycle. It is a good design tool and benchmark, and has been successfully applied to drive systems of hybrid electric vehicles and parallel hydraulic hybrid vehicles. However, due to the prediction of vehicle speed, the application of dynamic programming algorithm in the optimization of energy management strategy for hybrid vehicles is limited. The intelligent energy management strategy of driving condition, driver's driving cycle and current driving mode is identified by neural network and fuzzy logic controller. After learning tests, the learning vector of the neural network of road type and congestion degree is determined in advance. Then, the driving mode and the driving cycle are determined by fuzzy logic, so that the energy allocation is intelligent, to achieve the best fuel economy.

2. Fuzzy control strategy

2.1 Introduction to fuzzy control strategy

Fuzzy control strategy is a new control strategy developed in recent years with advantages as the fact that an accurate mathematical model is not required for controlled objects, that a decision-making table based on which control size is determined is organized and controlled according to the manual control rule (Zhou et al., 2014). Its starting point is to achieve the highest overall efficiency of the hybrid system by comprehensively considering both working efficiency of the fuel cell and the battery (Kreitlein et al., 2015; Ansari et al., 2016). Though the fuzzy control strategy is similar to the real-time control strategy, the fuzzy logic control strategy has good robustness compared with the real-time control strategy (Dweiri et al., 2016).

The core of fuzzy control is to use fuzzy language condition statements as control rules to implement control. It is a kind of artificial intelligence control strategy based on expert's knowledge (Tir et al., 2016). The fuzzy control system generally includes a fuzzy controller, an input/output interface device, a detection device, a controlled object and an actuator, while the fuzzy controller is the core part of the fuzzy control system (Dweiri et al., 2016). Fuzzy rules of the fuzzy controller are language control rules based on fuzzy conditional language description, so the fuzzy controller is also called as the fuzzy language controller (Büyüközkan and Güleryüz, 2016). It is usually achieved by computer which can be a single chip microcomputer, an industrial personal computer and other microcomputer according to needs of the control system, while the fuzzy control algorithm is implemented by computer programs and hardware (Khayyam and Bab-Hadiashar, 2014, Chen et al., 2016). The fuzzy controller, by computer, based on fuzzy input information transformed from the accurate quantity, is able to carry out fuzzy reasoning and give fuzzy output decision according to language control rules. The fuzzy input information is once again transformed into the accurate quantity to feed back to the controlled object. The functional block diagram of fuzzy controller is shown in Figure 1, from which it can be learnt that fuzzification with accurate quantity is to transform linguistic values of linguistic variables into a fuzzy subset in an appropriate domain of discourse. And a group of fizzy conditional statement is used to constitute fuzzy control rules, fuzzy relationship determined by which is calculated and used to carry out fuzzy decisions on output information to complete transform from fuzzy quantity to accurate quantity.

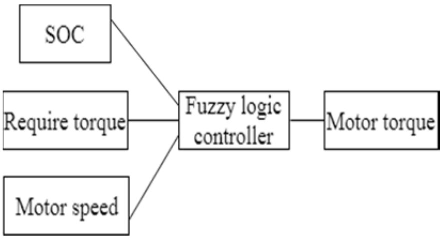

Figure 1: Schematic Diagram of Fuzzy Controller

Performance of a fuzzy controller mainly depends on the structure of the fuzzy controller, fuzzy rules used, synthetic reasoning algorithm, proportion quantizing factor of domain and fuzzy decision making methods. The structure of the fuzzy controller is divided into the single variable fuzzy controller and the multivariable fuzzy controller from the angle of input and output, while the conventional fuzzy controller is a single variable fuzzy controller. The input variables of the fuzzy controller can choose error, error variety and change of error variety, while the output variable generally chooses change of the controlled quantity. Usually, number of input variables of the fuzzy controller is called dimension of the fuzzy controller.

2.2 Establishment of fuzzy control rules

The fuzzy control rules are a summary of system control experience, which is expressed by fuzzy conditional statement. The process of establishing fuzzy controller's control rules is the process of using language to summarize the manual control strategy. The most commonly used methods of fuzzy control rules are empirical induction and inference synthesis. It is known that it is difficult to summarize the experience of the fuel cell and battery hybrid drive system. According to use characteristics of automobiles, the empirical induction method is used for analysis and research on power performance and economic performance during driving. The fuzzy control rules set according to operating characteristics of the fuel cell and battery hybrid drive system are set out in Table 1.

Table 1: Fuzzy Control Rules

	Negative big	Negative small	Zero	Positive small	Positive big
Lower	1.0	1.05	1.1	1.2	1.25
Low	0.9	1	1.05	1.1	1.2
Moderate	0.8	0.9	1	1.05	1.1
High	0.5	0.8	1	1	1.05
Higher	0	0.75	0.9	0.9	1

Fuzzy rule is the principle of determining fuzzy controller from input to output. It directly affects the output of fuzzy reasoning. Therefore, the rationality of fuzzy control rules is directly related to the effect of fuzzy control. The fuzzy rules designed in this paper mainly have the following principles. First, when the battery is in the normal range, the vehicle is mainly driven by the engine. When the demand torque is too large, the motor is only auxiliary drive. Second, when the battery value is too high, the vehicle is still driven by the engine. When the demand torque is greater than the optimal engine output torque, the engine remains in the optimal working area. By using the electric energy stored in the battery to drive the motor, additional torque is provided to ensure that the vehicle torque is satisfied. When the battery value is low, the engine working point should be raised a little bit. By using the torque outside the drive to charge the battery, the balance of the battery power is guaranteed. It should be noted that, in the above circumstances, the normal and safe driving of vehicles should be guaranteed first, which is the premise of all control. Simulation is an important technology in the development and testing of hybrid electric vehicle. In the process of vehicle design, good simulation is of great help to the adjustment of design scheme and the optimization of relevant parameters. The cost of research and development is reduced and the research and development cycle is shortened. Meanwhile, the quality of design is improved. In the process of simulation modeling, we can simplify the processing of the parameters which are not concerned or unimportant, and make the model simple, easy to transplant and simulate. The main parameters used in vehicle modules is as shown in Table 2.

Table 2: Main parameters used in vehicle modules

Parameter	Value	Remarks
Vehicle quality	1130kg	It is calculated according to the manufacturer to provide curb quality.
Air resistance coefficient	0.35	Provided by the manufacturer
Frontal area	$2.62m^2$	Provided by the manufacturer

At present, according to different energy and control signal transmission paths in the simulation process, the simulation modeling of hybrid vehicles can be divided into two categories: backward simulation and forward simulation. In the backward simulation, the composition of the vehicle system itself is taken as a point of focus. Economic optimization is the ultimate goal, in order to solve the problem of matching parameters of various components. However, the driver model was not considered in this process. Therefore, it is mainly used in the comparison and evaluation of different schemes, which is not suitable for the control algorithm and control strategy development. Unlike backward simulation, the forward model has a driver model so that the model input can be a vehicle control device such as an accelerator pedal, a brake pedal and a steering system. After the control input is parsed, it is converted to demand torque information and transmitted in the direction of vehicle power. Eventually, torque information is transmitted to the wheels to drive the vehicle.

3. Analysis of simulation results

3.1 Analysis of simulation data

Due to the fact that domestic standards related to fuel cell electric automobiles are blank, relevant foreign performance indicators are only choices for dynamic and economic analysis. Evaluation parameters for fuel cell electric automobiles given by Michelin Challenge Bibendum which is invested and held by a well-known tire company are used in this paper. There are a wide range of automobiles involved, including two wheeled vehicles, passenger cars, buses and commercial trucks with models including traditional internal combustion engines, hybrid automobiles, electric cars, etc. The Challenge Bibendum is the premier world event for clean and safe cars and has received widespread attention. The performance rating indexes of the passenger car used in the Challenge Bibendum are shown in Table 3.

Table 3: Performance Rating Indexes for Passenger Cars Used in the Challenge Bibendum

	Class A	Class B	Class C	Class D
Accelerating ability	≤10.0s	≤12.0s	≤17.0s	＞17.0s
Braking ability	≤32m	≤36m	≤40m	＞40m
Driving range	≥900km	≥450km	≥250km	＜250km
Fuel economy	≤3.50L/100km	≤5.50L/100km	≤7.50L/100km	＞7.50L/100km

Note: Acceleration performance refers to acceleration time of the vehicle from 0 to 100km/h. Braking performance refers to the distance travelled by the vehicle from the time travelling at the initial speed of 80km/h to the time of complete stop. Driving mileage refers to the distance which the vehicle with the tank full of oil can travel at the economical speed. Fuel economy refers to the amount of fuel consumed by the vehicle running above 100km at the speed of 70km/h.

Table 4: Power Performance Results of Fuel Cell Simulation

0~50km/h acceleration time	4.2s
0~100km/h acceleration time	13.9s
Maximum speed	145km/h
Maximum climbing speed (20km / h)	＞30%
Maximum acceleration	$4m/s^2$
Travel distance within 10s	145.9m
Braking distance (starting speed 80km / h)	39m
0.5km acceleration time	22s

According to the above data, it can be learn that performance indexes of the vehicle after simulation completely meet the initial power requirements. Compared to performance of traditional internal combustion engine cars, the fuel economy of a fuel cell hybrid electric vehicle has been greatly improved with only one shortcoming as declining dynamic acceleration performance. With evaluation rating for Michelin Challenge Bibendum used, acceleration performance and braking performance of the vehicle are assessed as grade A and grade C separately, which is consistent with performance of fuel cell automobiles researched abroad, while the performance level is the same as that of a fuel cell electric vehicle developed by a university in china. Water is the only reaction production of the fuel cell electric vehicle, at the same time, carbon dioxide and hydrocarbons are not contained. Therefore, the emission level is grade A.

3.2 Simulation contrast analysis of fuzzy control strategy and on/Off control strategy

In order to ensure the comparability of economic calculation results, the SOC value of the battery before and after the cycle is 0, which eliminates influences of the energy carried by the battery on the economy with the same control strategy used. Specific calculation results are shown in Table 5.

Table 5: Simulation Economy Results of Fuel Cell Electric Automobiles

Fuel economy	UDDS condition	HWFET condition	70km/h cycle condition
Hydrogen consumption (L/100km)	44.8	31.4	27.3
Equivalent fuel consumption (L/100km)	3.2	2.6	2.1
Driving distance (km)	323	460.3	531.5

When the fuel cell hybrid power is used, the equivalent fuel economy of the vehicle under the above travel condition is between 2.5L/100km-3.4L/100km, which is greatly improved compared with the 7L/100km of the original vehicle. The driving mileage and fuel economy level of the automobiles are grade B and grade A separately according to the Bibendum evaluation standard.

Table 6: Battery SOC and Hydrogen Consumption of Fuel Cell Electric Automobiles under Different Control Strategies

SOC initial value		0.5	0.55	0.6	0.65	0.7	0.75	0.8
0.8Fuzzy control strategy	Battery SOC	0.523	0.574	0.609	0.659	0.709	0.750	0.778
	Hydrogen consumption (kg)	0.394	0.093	0.085	0.085	0.085	0.081	0.071
On/Off control strategy	Battery SOC	0.428	0.772	0.798	0.800	0.798	0.797	0.797
	Hydrogen consumption (kg)	0.396	0.178	0.166	0.144	0.119	0.096	0.074

It can be learnt from the simulation results that the two control strategies in the simulation have the same speed, that the storage battery SOC also changes in a reasonable range, that the hydrogen consumption of the fuzzy control strategy is less than that of the on/Off control strategy. When the initial value of the battery is relatively high, the hydrogen consumption of the two control strategies is close to each other; while when the initial value of the battery is low, the advantage of fuzzy control strategy is obvious. However, in the whole simulation process, the instantaneous hydrogen consumption of the fuzzy control strategy varies greatly, which puts forward higher requirements for performance of the fuel cell.

4. Conclusion

An economical domestic diesel locomotive is used in this paper as the vehicle prototype for simulation after virtual improvement of the fuel cell hybrid power. The powertrain selection and parameter determination are discussed, and the fuzzy control mode is used as the control mode of the fuel cell hybrid power system. After comparison and analysis on the results of fuel economy and dynamic performance under several typical operating conditions, the conclusion is drawn. By comparing performance of the traditional type of internal combustion engine car, it can be seen that the fuel economy of the fuel cell hybrid vehicle has been greatly improved with only one shortcoming as decreasing dynamic acceleration performance. Compared with different control strategies, it can be seen that the fuzzy logic control strategy reduces the hydrogen consumption compared with the on /off control strategy under the same simulation conditions.

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