Research on Matching Method of Power Supply Parameters for Dual Energy Source Electric Vehicles

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Abstract. A new type of power source is proposed, which is based on the traffic signal matching method of the dual energy source power supply composed of the batteries and the supercapacitors. First, analyzing the power characteristics is required to meet the excellent dynamic characteristics of EV, studying the energy characteristics is required to meet the mileage requirements and researching the physical boundary characteristics is required to meet the physical conditions of the power supply. Secondly, the parameter matching design with the highest energy efficiency is adopted to select the optimal parameter group with the method of matching deviation. Finally, the simulation analysis of the vehicle is carried out in MATLAB-Simulink, The mileage and energy efficiency of dual energy sources are analyzed in different parameter models, and the rationality of the matching method is verified.

1. Introduction

With the increase of on-board electrical appliances, pure electric vehicles are currently powered by batteries power supply. Not only does the batteries supply power to the motor, but it also needs to supply other high-power electrical equipment, which will lead to the batteries safety hazard or reduce the service life. At present, it is difficult to support the normal operation of electric vehicles on a single power supply, while the characteristics of super capacitor for long time and high power operation can meet the stringent requirements of electric vehicles on the power supply.

Most researchers focus on the energy management systems of these vehicles, for example, Soni[1], Rade[2] et al studied the energy management strategy of dual energy source electric vehicles based on the determination rules, Chen long[3], Kumar[4] et al studied the energy management optimization strategy of dual energy source electric vehicles. However, few researchers have studied the parameter matching of dual energy sources. In this paper, the coupling of power battery and supercapacitor is used as the power supply. After analyzing the characteristics of dual power supply, the matching target is completed by the error matching method.

2. Analysis of power supply characteristics

Before matching the dual source parameters, a mature batteries pack of pure electric vehicle is used as the research model. This study takes the vehicle parameters of the model, the dynamic performance
and mileage of the vehicle driving, and the physical conditions such as the size and quality of the on-board power supply are regard as the constraint conditions.

2.1. Power characteristic

Power characteristics of the power supply to meet the requirements of high performance dynamic characteristics of electric vehicles, determining the maximum power required for maximum speed, maximum climb and acceleration time of 0~100km/h.

\[
P_{\text{max}1} = \frac{1}{3600 \eta_e \eta_{PM} \eta_T} (mg V_{\text{max}}^3 + \frac{C_a A V_{\text{max}}^3}{21.15})
\]

\[
P_{\text{max}2} = \frac{1}{3600 \eta_e \eta_{PM} \eta_T} (mg V \cos \theta_{\text{max}} + mg V \sin \theta_{\text{max}} + \frac{C_a A V_i^3}{21.15})
\]

\[
P_{\text{max}3} = \frac{1}{3600 \eta_e \eta_{PM} \eta_T} \left( \frac{mg V T}{1.5} + \frac{C_a A V_i^3}{21.15 \times 2.5} + \frac{G V_i^3}{2 \times T} \right)
\]

\(\eta_e\) - Power discharge efficiency, \(\eta_{PM}\) - Permanent magnet synchronous motor efficiency, \(\eta_T\) - Drive efficiency of whole drive system, \(m\) - Fully loaded mass, \(g\) - Gravity coefficient, \(f\) - Coefficient of rolling resistance, \(C_a\) - Windward drag coefficient, \(A\) - Car windward area, \(V_{\text{max}}\) - Maximum speed, \(V_i\) - The speed of the climb, \(\theta_{\text{max}}\) - Maximum gradeability, \(V_r\) - Speed after the acceleration, \(T\) - Acceleration time, \(\sigma\) - Correction coefficient of rotating mass;

The peak power of a dual energy source electric vehicle is powered by supercapacitors, the power of power supply for dual energy source electric vehicles is

\[N_{\text{sc}} P_{\text{sc}} \geq \max(P_{\text{max}1}, P_{\text{max}2}, P_{\text{max}3})
\]

\(N_{\text{sc}}\) - The number of supercapacitors, \(P_{\text{sc}}\) - The power of a single supercapacitors.

2.2. Energy characteristic

Endurance mileage is an important performance indicator for car manufacturers or users. In this case, the mileage is higher than 150km design of electric vehicles. Estimating the endurance of an electric vehicle by running the 100km power consumption of an electric vehicle at constant speed.

\[
W = \frac{80% \times (7.2 \times 10^5 N_{\text{sc}} C_{\text{sc}} U_{\text{sc}}^2 + N_b C_{\text{b}} U_{\text{b}})}{150 \times \frac{100}{100}}
\]

\(C_{\text{sc}}\) - The capacity of a supercapacitor, \(U_{\text{sc}}\) - The voltage of a supercapacitor, \(N_{\text{b}}\) - Number of accumulators, \(C_{\text{b}}\) - A battery capacity, \(U_{\text{b}}\) - A battery voltage, \(W\) - The electric power consumed at a constant speed of 100 kilometres.

2.3. Physical characteristics

The quality and volume of the power supply affect the quality and volume of the vehicle, thus affecting the performance of the vehicle[5].

\[
N_b m_b + N_{\text{sc}} m_{\text{sc}} \leq M_{\text{max}}
\]

\[
N_b v_b + N_{\text{sc}} v_{\text{sc}} \leq V_{\text{max}}
\]

\(m_b\) - The quality of a single battery, \(m_{\text{sc}}\) - The quality of a single supercapacitor, \(M_{\text{max}}\) - Total power quality limits, \(v_b\) - The volume of a single battery, \(v_{\text{sc}}\) - The volume of a single supercapacitor, \(V_{\text{max}}\) - Total power supply limit.

2.4. Power parameter group
The limits of supercapacitors and accumulators in figure 1 are obtained through the calculation of (4) (5) (6) (7) under the condition of the power supply characteristics. There are 17,714 parameters in the black feasible region [Nb, Nsc]. How to determine the combination of supercapacitors and batteries is to optimize the selection of these parameters according to the driving conditions of electric vehicles and the energy management strategy of the vehicle.

3. Deviation matching method based on road condition

The matching parameters and energy management strategy of dual energy sources are strongly coupled[6]. The energy management strategy of a dual-energy electric vehicle can affect the distribution of energy in the power supply of supercapacitors and batteries. Because of the difference in operating conditions, too much energy is consumed in batteries or supercapacitors, and electric cars stop working, while batteries or supercapacitors save a lot of energy. This leads to the irrational use of power supplies. This paper presents a method to obtain the optimal matching parameters of dual energy sources power supply based on the driving condition in ensuring the power supply characteristics. The aim of this method is to make the supercapacitors and the accumulator at the same time reach the minimum energy value and improve the energy efficiency of the power supply.

3.1. Power conversion model

The UEDC cycle condition in figure 2 is regard as the actual driving condition. The powers of electric vehicles can be obtained according to the principle of the conservation of motor power.

\[
P_p = \frac{u_a (mgf + mgi)}{3600 \eta_{PM} \eta_T} + \frac{C_a u_a^2}{21.25} + \frac{m u_a}{dt}
\]

\(P_p\) - Power required for power supply, \(i\) - Road grade, \(u_a\) - Running speed.

![Figure 2. Speed and power of NEDC.](image)

![Figure 3. Matching deviation.](image)
3.2. **Power ratio of power supply under cyclic working condition**

In this paper, the double power source electric vehicle energy management strategy is normal. High power charging and discharging is carried out by super capacitor, and the battery bears low power charge discharge, braking energy is recovery by supercapacitors. not only can it make the electric car with good dynamic performance, but also avoid the peak discharge of batteries. When the power of the power supply is less than the maximum power of the batteries, the batteries provides energy(Eb). When the power supply power is less than zero, the power of the supercapacitors is recovered(Ecov). When the power of the power supply is greater than the maximum power of the batteries, the supercapacitors provides energy(Esc).

\[ P_{b_{\text{max}}} = C_b \bullet U_b \bullet k_{\text{max}} \bullet N_b \]

- **Pbmax** - The maximum discharge power of batteries,
- **Kmax** - Maximum discharge ratio

Energy consumption is the product of power and time. The ratio of the energy of the batteries and the supercapacitors in the cycle condition is obtained.

\[ K' = \frac{N_c C_b U_b}{\frac{1}{2} N_{sc} C_{sc} U_{sc} \times (3.6 \times 10^{-3})} \]

\[ \delta = \left| K' - K \right| \]

The matching deviation can evaluate the operation of the parameter group under cyclic condition. The smaller the matching error is, the closer the dual energy source ratio in the matching parameter is to the dual energy source ratio required in the road condition. The matching deviation for the above mentioned 17714 sets is shown in figure 3.

The matching deviation of the 10313 parameter group [99,113] in the matching deviation is 2.410-4, which is the smallest parameter group. It selects 99 batteries and 113 supercapacitors. Its main parameters are listed in table 1.

| Unit of Parameter | Accumulator | Supercapacitors | Total |
|-------------------|-------------|-----------------|-------|
| Quantity/(single) | 99          | 113             | 212   |
| Mass/(kg)         | 186.12      | 96.05           | 282.17|
| Volume/(m³)       | 0.085       | 0.047           | 0.132 |
| Energy/(kwh)      | 25.344      | 5.706           | 31.050|
| energy/(kwh/kg)   | 0.136       | 5.94×10⁻²       | 0.110 |

The method of matching deviation is to optimize the parameters of the driving condition and energy management strategy. First, the power of the power supply for a cycle condition is calculated. The power of the power supply is allocated by the energy management strategy to obtain the energy ratio of the supercapacitors and the batteries in the cycle condition. Finally, the matching deviation is calculated and the optimal parameter group is selected.

4. **The simulation analysis**

Building the vehicle model in MATLAB-Simulink. When the value of the SOC of the supercapacitors or the batteries is less than 20%, the electric vehicle power supply discharge ends in the NEDC cycle, and the simulation stops. A total of 99 batteries and 113 supercapacitors batteries were used. The input operation model is based on 1 cycle condition and 25 cycle conditions. The energy usage of the supercapacitors is shown in figure 4. The energy usage of the batteries is shown in figure 5.
Figure 4. Supercapacitor energy.

The simulation stopped at 27784s. At this point, the supercapacitors are below the cutoff value of 1.140 KWH, and the range is 256787m, which meets the design requirements. The batteries have 2.37 KWH energy to use, and the power utilization efficiency is 92.4%.

The NEDC was tested by taking the number 2131, 10313, 15812. The test results are as table 2. The comparison test results of the three parameter groups are very straightforward to show that the smaller parameters of the match deviation are more efficient and having the longest range. The results show that the parameters matching method based on the road condition is reasonable and efficient.

Table 2. Comparison of simulation result.

| Parameter sequence number | Parameter set \([N_b, N_{sc}]\) | Matching deviation | Simulation stop time/s | Range/m | Energy efficiency/% |
|---------------------------|-------------------------------|--------------------|------------------------|--------|---------------------|
| 2131                      | [53,305]                      | 1.5                | 16859                  | 155987 | 67.1                |
| 10313                     | [99,113]                      | 2.4 \(\times\) 10^{-4} | 27784                  | 256787 | 92.3                |
| 15812                     | [72,201]                      | 0.12               | 22157                  | 191718 | 79.8                |

5. Conclusion

This paper takes a mature electric car as the design prototype. A parameter matching method based on road condition is proposed. The analysis results show that the parameter matching method is reasonable. Be up against a complex road in a region, after matching of the dual energy source, and then the coupling mechanism of dual energy source is studied and the power control strategy is formulated. In view of the characteristics of multi terrain and multi road in our country, This method has certain reference value.

6. Reference

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