Modeling and Simulation of Single Battery Load Isolated Electric Vehicle Based on Simulink

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Abstract. The load isolation electric vehicle improves the range of electric vehicle, which separates the concept of power and energy, so that the engine can always work in the most economical operating area. Based on Simulink, a single battery load isolation electric vehicle model is established for a mini car. According to the requirements of vehicle performance indexes, the parameters of vehicle system model, gasoline generator set, battery pack and motor model were matched. In the process of accelerating the average speed to the set maximum speed, the battery voltage curve and the motor output power are analyzed. The analysis shows that the battery has no overvoltage danger and the motor does not exceed the peak power, thus verifying the feasibility and superiority of the model.

1. Introduction
In the face of severe resource and environment problems, developing electric vehicle industry has become a trend of automobile technology development. Pure electric vehicles abandon the complex mechanical structure of traditional cars. They use batteries as energy storage devices to provide electric energy for cars and motors as driving devices [1]. They have the advantages of simple structure, zero emission and low noise.
However, due to technical reasons such as low power density and energy density, the battery will only have a short range of electric vehicles [2]. The load isolation vehicle is composed of gasoline generator set, battery pack, motor and so on. It liberates the engine from the energy drive device and keeps the engine working at the optimum steady-state operating point to charge the battery pack, thus improving the range of the electric vehicle. Two or more groups of batteries can be charged and discharged alternately to avoid the problems of overcharge, overdischarge and overtemperature [3]. Based on Matlab/Simulink, a load isolation electric vehicle model is established in this paper. Since the number of battery packs has little influence on the modeling and simulation in this paper, in order to simplify the complexity of the model, only a load isolated EV model with a single battery group is established. In the model, the parameters of the vehicle power system and the main components are matched, and the performance of the vehicle is simulated.

2. Build the Body Model
The components needed by SIMULINK were rebuilt and encapsulated subsystems. This method can be represented by a group of modules or a single graphical subsystem module, which greatly enhances the readability of the system model. However, the parameters of each module in the subsystem need to be reset during the dynamic system simulation. Encapsulating a subsystem means encapsulating a subsystem that has already been built to have a certain function. The purpose is to generate user-defined modules that are completely consistent with the functions of the subsystem [4-5].
To establish the model of load isolation electric vehicle, it is necessary to establish a vehicle longitudinal dynamics model first. Then the model is encapsulated into the vehicle longitudinal dynamics subsystem, and the parameters are set according to the requirements of the model[6]. In this paper, CHANG AN BENBEN electric vehicle is selected. The parameters of the sample car are shown in Table 1. The initial longitudinal velocity was set at 0.11 m/s.

### Table 1. Vehicle parameters.

| number | parameter | Value          |
|--------|-----------|----------------|
| 1      | length/width/high (cm) | 3730/1650/1560 |
| 2      | Total mass (Kg)       | 1125           |
| 3      | Coefficient of air resistance Cd | 0.33         |
| 4      | Windward area (m²)    | 1.9            |
| 5      | Transmission efficiency η | 0.93      |
| 6      | The wheel radius (mm) | 641            |
| 7      | Rolling drag coefficient f | 0.01      |

### 3. Parameter Matching and Model Building of Single Battery Group

The key to the power system of load isolation electric vehicle lies in its energy storage device matching. Battery is still the best choice of electric vehicle energy storage device because of the mature technology and reasonable price. Various factors should be considered comprehensively when selecting power batteries [7]. High energy density batteries are key to achieving the target range for electric vehicles. The integrated management system and thermal management system help display the battery SOC level and temperature in real time. These measures can prolong the life of the battery. Referring to the above factors, considering the battery usage of domestic and foreign electric vehicle manufacturers, existing equipment and safety, the model uses lithium iron phosphate battery.

Assuming that the model runs at an average speed of 42 km/h, the power output required by the motor is:

$$P_i = \frac{1}{\eta} * \left( \frac{Mg_\text{f}}{3600} u_1 + \frac{C_D A}{76140} u_1^3 \right)$$

(1)

Where, $\eta$ is the efficiency of transmission system; $M$ is the preparation mass; $f$ is the rolling resistance coefficient; $u_1$ is the average speed; $C_D$ is the air resistance coefficient; $A$ is windward area.

Therefore, the output power of the battery pack is:

$$P_{out} = \frac{P}{\eta_{mo}}$$

(2)

Where $P_{out}$ is the average power; $\eta_{mo}$ is the motor efficiency, and the value is 0.9.

The capacity of the battery is:

$$C_b \geq \frac{1000 P_{out}}{\lambda * U_1}$$

(3)

Where, $\lambda$ is battery discharge rate; $U_1$ is the battery voltage.

By substituting the parameters of the sample vehicle into Equations (1), (2) and (3), it can be seen that $P_i = 2.21\text{kW}$; $P_{out} = 2.42\text{ kW}$. $C_b \geq 28.7\text{ Ah}$, where $k$ is the value 1, $C_b = 32\text{ Ah}$.

Model battery selection is based on average speed and average power. In order to ensure power and charge and discharge requirements, the load isolation electric vehicle selected 82 V, 100 Ah lithium iron phosphate battery. The internal resistance of a single battery is 30 mΩ. Therefore, the internal resistance of a battery string is 0.069 mΩ.
4. Parameter Matching and Modeling Simulation of Engine and Generator

The output power of the generator is the first factor to be considered when selecting the generator. When the electric quantity reaches the alarm level, the generator needs to work to meet the steady-state driving power of the electric vehicle \( [8] \). The engine is completely separated from the load and only serves as an energy conversion device to provide electric energy to the battery in time. The model chooses the average speed and the average power as the reference index to select the engine \( [9] \). According to the average index, the volume and power of the engine can be greatly reduced, the weight of the car can be reduced, and the economy of the electric vehicle can be improved.

The power of the generator is roughly equal to the sum of the driving resistance of the vehicle at the average speed, namely:

\[
P_g = \frac{1}{\eta_m \eta_m \eta_{bo}} \left( \frac{Mg f}{3600} u_1 + \frac{C_D A}{76140} u_2^3 \right)
\]

Where, \( \eta \) is the efficiency of transmission system; \( \eta_m \) is the motor efficiency; \( \eta_{bo} \) is the discharge efficiency of the battery, which is 0.96.

We can get \( P_g = 2.6 \) kW, so let's take \( P_g = 5 \) kW.

Taking all these factors into account, the four-stroke gasoline engine is still the most ideal engine for the load isolation electric vehicle generator set.

5. Motor Parameter Matching and Model Simulation

Motor has a long history of development, and motor technology has been very mature \( [10] \). At present, there are many kinds of electric motors used in automobiles. Induction motor, dc motor, AC motor and switched reluctance motor is the most widely used. Digital scoring algorithm is used to compare the performance of four kinds of motors. Considering all the factors, the model selects the low power AC induction motor as the driving motor of the load isolation electric vehicle. According to the power parameters of the battery pack and the relevant provisions on the power level of the motor, the low-speed motor with rated power of 10 kW and peak power of 16 kW is selected for the model.

The conversion relation between the maximum speed of the driving motor and the maximum speed of the vehicle is:

\[
n = \frac{v_{max} i_n i_m}{0.377 r}
\]

Where, \( i_n \) is the speed ratio of the main reducer; \( i_m \) is transmission speed ratio; \( r \) is the radius of the car wheel.

The model eliminates the transmission system, so \( i_n = 1 \). According to the set maximum speed of 75 km/h. The maximum speed of the motor was determined to be 4000 r/min, \( n = 4500 \) r/min, and the coefficient \( \beta \) of motor extended constant power zone was 2.5. So the rated speed of the driving motor is 1800 r/min. According to formula (6), the rated torque of the motor is 56N·m.

\[
T = \frac{9550 P}{n}
\]

6. Analysis of Simulation Results

The model is connected with an oscilloscope module to output speed at the speed output port. The model simulates ev acceleration from an average speed of 43 km/h to 75 km/h. Observe the voltage change curve of the battery string (Figure1) to check whether there is an overvoltage hazard. Whether the output power of the motor (Figure2) is in danger of exceeding the peak power. The results show that there is no overvoltage danger in the battery and the motor power does not exceed the peak power.
Figure 1. Voltage curve of the battery string.

Figure 2. Voltage curve of the battery string.

7. Conclusion
Through MATLAB/SIMULINK software, the modeling and simulation of the load isolation electric vehicle are carried out. The simulation results meet the expected results. The feasibility of load isolation electric vehicle is verified. The motor and gasoline generator used in this model are slightly larger, so these components can be optimized in the future to achieve better results. The analysis of the simulation results in this paper provides the theoretical and experimental data basis for the future optimization design and the establishment and simulation of the load isolation electric vehicle model with two or more groups of batteries, so it has a very important guiding significance.
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