Research Continued Mileage of Pure Electric Vehicles Based on Energy Management Control Strategy

Guo Minrui and Cheng Lei
College of mechanical and energy Engineering, Huanghuai University, Henan Zhumadian, China
814293109@qq.com

Abstract. In order to achieve the goal of increasing the mileage of pure electric vehicles, a pure electric vehicle was used as the research object, and the parameters of the battery pack were designed and matched, formulate the energy management control strategy based on threshold value, simulate the continuous driving distance of the vehicle with the help of ADVISOR simulation software, under the premise of not affecting the power of pure electric vehicles, the optimal threshold of energy management strategy that effectively increases the driving range of the vehicle is obtained, that is the battery pack's the state of charge is more than 45% and less than 50%, indicate that the energy management control strategy is correct and feasible.

1. Introduction
In 2015, China's production of new energy vehicles ranked first in the world, and foreign countries are also accelerating the development of electric vehicles. In December 2013, BYD officially announced that its electric bus K9 product was put into operation in London's public transport system in the United Kingdom. It can fly over 270 km without charge at one time. This is the first pure electric bus in London[1]. The traditional internal combustion engine has a mileage of more than 500km at one time. Some cars can even reach more than 1000km (such as Volkswagen Polo), Most electric cars have a range of between 100 and 300km in an ideal state, compared with the traditional car gap. While the famous American pure electric vehicle Tesla Model S is full of electricity, the mileage of one trip is 400–500km[2]. Compared with the driving range of pure electric vehicles both at home and abroad, compared with the traditional internal combustion engine vehicles, it can be seen that the driving range of pure electric vehicles still has more room for development. The pure electric car is powered by battery pack, the battery pack has limited energy. driving mileage is the key issue restricting the industrialization of pure electric vehicles. Therefore, it is necessary to start with the efficient use of vehicle energy, save and optimize the use of energy, and formulate a good energy management strategy to ensure that the driving motor can output effective torque and power rationally and prolong the driving range of pure electric vehicles. When the state of charge (SOC) of the battery pack decreases to a certain value, the motor will stop rotating due to the decrease of the battery terminal voltage, which will not only affect the service life of the motor and the battery pack, but also affect traffic safety[3]. How to develop a good energy management control strategy, choose to match the parameters of the battery pack to improve the driving range of pure electric vehicles, this is the key technology of pure electric vehicles.
2. Battery pack parameter selection

2.1. Battery type of choice
Lithium polymer battery energy density ratio, single high nominal voltage, safety performance, cycle life of more than 2000 times, and can discharge a larger current, high temperature performance, single cell capacity, no memory effect, light weight, pollution-free, environmentally friendly[4]. Such as BYD's electric bus K9, Tesla electric vehicles are used lithium-ion battery pack, indicating that it has the characteristics of other batteries do not have, so choose lithium polymer battery.

2.2. Battery energy and the number of choices
The total voltage of the battery pack should be slightly larger than the rated voltage of the drive motor to prevent the battery pack voltage from affecting the driving range of the electric vehicle. The rated voltage of the battery pack is 281.6V. The larger the vehicle driving range, the greater the battery power. Battery energy to ensure the driving range of the vehicle. The size of the driving range of electric vehicles is an important indicator of economic performance. Select the appropriate number of battery packs to ensure their driving range requirements. By the size of driving range of electric vehicles, can estimate the number of batteries required. In this paper, the specifications of the lithium polymer battery is 3.2V, 25Ah, according to the design requirements of electric vehicle in full charge of 40km / h speed uniform driving, the mileage is not less than 140km. The required power \( P \) is:

\[
P = \frac{V_a}{3600\eta} \left( mgf + \frac{C_D A V_a^2}{22.15} \right)
\]

In the above formula, \( m \) is the mass of the vehicle; \( g \) is the acceleration of gravity; \( f \) is the rolling resistance coefficient; \( C_D \) is the air resistance coefficient; \( A \) is the windward area; \( V_a \) is the speed of the electric vehicle. Then the vehicle travels \( S = 140\) km at a constant speed with energy \( W \):

\[
W = Pt = P \frac{s}{V_a}
\]

Then the number of batteries required can be calculated by the following formula:

\[
W = \frac{n \mu C E_0}{1000}
\]

In the above formula, \( n \) is the number of needed batteries; \( \mu \) is depth of battery discharge, the value is 0.8; \( E_0 \) is working voltage of the battery, the value is 3.2v; \( C \) is the capacity of the single battery, the value is 25Ah. After calculation, the number of single cells is 352, constitute a way for every 4 lithium polymer monomer cells in parallel to form a battery unit, and then in series with 88 battery cells, the total battery capacity of 100Ah. The battery pack parameters are shown in table 1.

| Table 1. Battery pack parameters |
|----------------------------------|
| parameters                        | the value          |
| Single battery rated voltage      | 3.2 (V)            |
| Single battery rated capacity     | 25 (Ah)            |
| The number of single cells        | 352                |
| Total battery capacity            | 100 (Ah)           |

3. Energy management strategy formulation
Pure electric vehicles due to the limited number of battery pack, limited vehicle energy, the mileage will not reach the standard of traditional fuel vehicles[5]. There are two ways to solve this problem. Firstly, rely on the battery technology breakthrough to develop a larger total capacity of the battery pack, single battery terminal voltage is higher, the battery pack is better, faster charging battery, this is
more difficult to achieve. The second is to develop scientific and rational energy management strategy, reasonable allocation of battery energy, reduce energy consumption, improve energy efficiency. Improve driving range without affecting vehicle power and safety. At present, after optimization and redevelopment of the energy management control strategy, it can effectively increase the driving range of the vehicle.

The pure electric vehicle energy management system includes the estimation of SOC, energy management control strategy, regenerative braking energy recovery, etc. Energy management control strategy is a top priority. It not only controls the switching of various working modes of the vehicle, but also controls the rational distribution of energy flow. There are many types of energy management control strategies, such as logic threshold control strategy, fuzzy neural network control strategy, instantaneous optimization control strategy, global optimal control strategy, etc. Pure electric vehicles due to the use of a single energy source, energy management control strategy in two ways: First, the allocation of energy efficiency optimization vehicle, the second is the appropriate value of the SOC limit the motor torque output. Since pure electric vehicles only use batteries for power supply, the energy management control strategy is simple and the optimized follow-up mileage is obviously improved. General rules of the use of energy management strategies. According to the battery pack SOC value and drive motor efficiency, when the SOC value is different, the motor output power and torque changes. First set a good relationship between SOC and motor output power, when the SOC is reduced to a certain value, limit the motor power and torque output, to meet the dynamic and safety premise to improve the driving range. This strategy algorithm is effective and easy to operate, in practice, a large number of applications. The control method adopts the threshold control method., can effectively solve the motor and battery energy input and output problems. The method first sets a SOC threshold (between 30% and 40%) of the remaining energy. If the SOC estimation value is higher than the threshold, the output torque of the motor is not limited when the driver depresses the accelerator pedal. If the SOC estimate is below the threshold and even if the driver depresses the gas pedal, the energy management strategy limits the motor output torque, but in exceptional driving conditions such as overtaking or climbing, the motor output torque is relieved. Energy management control flow chart is as follows:

In Figure 1, the acceleration pedal signal is converted into the demand torque value of the motor through the sensor, and the corresponding relationship between the acceleration pedal signal and the demand torque is made according to the driver's intention. Optimize the output torque of the motor through the energy management control strategy. According to the above control flow chart, the control strategy of the threshold value of the rules is established. When the pure electric vehicle is driving normally, the requirements of this strategy are as follows:

![Energy management control strategy flow chart](image-url)
(1) if the battery group SOC is more than threshold value, the energy management strategy does not limit the output power and torque of the motor to ensure the power demand of the vehicle.

(2) if the battery group SOC is less than or equal to the threshold value, the energy management strategy limits the output power of the motor, which is 80% of the rated power.

(3) once in special conditions, such as driving state when overtaking or climbing hill, pure electric vehicles demand for motor torque is bigger, the energy management strategy relieves the motor torque limit, meets the needs of the vehicle with high torque, to ensure that the power performance and security.

4. Simulation analysis and experimental verification of vehicle continuous mileage

4.1. Input of battery pack and other parameters of the vehicle

The ADVISOR is a software for simulation analysis of traditional internal combustion engines, fuel cell vehicles, hybrid electric vehicles and pure electric vehicles. Travel distance with ADVISOR software simulation of vehicle, to reduce the electric car research and development cycle, compare the difference of driving range under different energy management strategies, first the input battery parameters and the other parameters, then select the simulation conditions.

4.2. Select simulation conditions

The ADVISTOR software offers three simulation scenarios: Standard Drive Cycle, Multiple Cycles and Test Procedures. Users can choose to simulate different operating conditions according to different requirements. With reference to the requirements of the Ministry of Industry and Information Technology of People's Republic of China, according to the actual conditions in the roads, choose the CYC-NEDC operating conditions under the standard cycle conditions to simulate the driving range. The relationship between speed and time of CYC-NEDC cycle is shown in Figure 2.

![Figure 2. CYC-NEDC cycle conditions diagram](image)

4.3. Driving range simulation results

ADVISOR software can be used to simulate the pure electric vehicle performance and mileage, etc, this part of the simulation includes two parts.

The first part need set the battery charged status (SOC) is 100%, the end of the discharging, SOC was 20%, running multiple NEDC driving cycles, the simulation results of the driving range of the pure electric vehicle, which determine the choice of battery parameters and the other parameters can meet the design index. The second part aims at increasing the mileage of continuous driving, and divides the total mileage into two stages. The initial stage is SOC from 100% to 50%, 45%, 40%, the second phase is SOC from 50%, 45%, 40% to 20%, energy management strategy limits motor output power, the sum of the two is the total driving range, compared with travel distance of the first part of
each other, verify that the control strategy can increase the range of pure electric vehicles, learned that the energy control strategy is scientific and reasonable. Verify whether the control strategy increases the cruising range of pure electric vehicle and whether it is scientific and reasonable.

(1) Use the method of the first part, under the NEDC cycle conditions, the SOC value of the battery sets between 100% -20%, after simulation the driving range S is 147.8km, this driving range can reach the initial design specifications.

(2) Use the method of the second part, the threshold value SOC takes different values and limits the output torque of the motor when it is lower than the threshold value. Import the control policy into the ADVISOR’s control policy library. In the first stage, the SOC value of the pure electric car battery pack is from 100% to 50%, and the mileage of this stage is 91.8km. The second stage sets the SOC value from 50% to 20%, and the mileage of this stage is 72.9km. The overall mileage of the vehicle S1 is 164.7km.

(3) Similarly, Use the method of the second part, In the first stage, the SOC value of the pure electric car battery pack is from 100% to 45%, and the mileage of this stage is 97.8km. The second stage sets the SOC value from 45% to 20%, and the mileage of this stage is 62.6km. The overall mileage of the vehicle S2 is 160.4km. S3 is 156.7km. Simulation comparison chart can be obtained by using different threshold values to simulate the mileage, as shown in figure 3.

![Continuous mileage (km)](image)

**Figure 3.** Compare the mileage simulation chart with different threshold values

According to figure 3, and collate the above data, under different SOC values, the following table 2 is obtained.

|       | The SOC range | The driving distance |
|-------|---------------|---------------------|
| S     | 100%—20%      | 147.8               |
| S1    | 100%—50%      | 50%—20%             | 164.7               |
| S2    | 100%—45%      | 45%—20%             | 160.4               |
| S3    | 100%—40%      | 40%—20%             | 156.7               |

After analyzing the above simulation results, S1, S2 and S3 adopted the energy management control strategy based on the threshold value, and the continuous mileage increased by 11.4%, 8.5% and 6.0%, respectively compared with those without the strategy. According to the above simulation results, in order to achieve the goal of increasing travel distance, at the same time balancing the power performance of vehicle, the torque of the motor limit point SOC values between 50% - 45%, that is, the threshold value of the energy management control strategy.

5. **Conclusion**
Different energy management control strategies will have certain impact on the driving range of pure electric vehicle. By adopting the NEDC cycle driving condition and setting the battery SOC range between 100% and 20%, the key point is to find the optimal threshold of different energy management control strategy, that is, the SOC value is between 50% and 45%, it can balance the power of the vehicle and the driving range, and compared with driving range of the new control strategy and the original control strategy, there has been some improvement in the mileage., indicate that the energy management control strategy is scientific and rational.

References
[1] Chen Xing, Xie Mingwei. Estimation of residual driving distance of electric vehicles with fuzzy energy consumption.[J]. Journal of Henan University of Science and Technology, 2017(2):28-34.
[2] Li Jinxia, Wu Qinmu. Estimation of SOC of lead-acid batteries for electric vehicles [J]. Automation and instrumentation,2015 (7) :221-222.
[3] Zhou Bin. Study on the calculation of SOC and continuous mileage of pure electric vehicle power batteries [D]. Hefei University of Technology, 2014.
[4] Du Shuang. Research on key technologies for energy management of dual energy source pure electric vehicles [D].Jilin University, 2015.
[5] Wang Guoqiang,Wang Zhixin. Research on optimization of new electric vehicle frame structure [J]. Automation and instrumentation,2016 (7) :67-69.