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Energy Storage Principle and Technology Optimization of Battery Charging Efficiency of New Energy Vehicles

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Abstract: With the increasing global energy and environmental problems, the disadvantages of traditional energy are becoming increasingly apparent. As a clean emerging energy, electric energy can not only alleviate the shortage of traditional energy, but also improve environmental problems. Therefore, the development of electric vehicle industry is inevitable. However, with the expansion of the scale of electric vehicles, their charging and discharging behavior will have an impact on the operation of the power grid, so it is necessary to optimize the charging efficiency(CE) of new energy vehicles(NEV). Based on the principle and technology of energy storage, this paper studies the optimization of battery CE of NEV; This paper briefly introduces the structure of new energy vehicle, puts forward the principle and technology of energy storage, and discusses the basic structure and working principle of lithium battery of new energy vehicle and the model of power battery; Finally, based on the principle and technology of energy storage, the CE of new energy vehicle battery is optimized. Through the design of optimization control strategy for CE of new energy vehicle and the comparison of charging schemes in the dc/dc circuit system modeling, analysis and test system, the effectiveness of the scheme to improve CE in this paper is verified.

1. Introduction

In terms of energy conservation and emission reduction, even though electric vehicles have such great advantages, they still have not achieved industrialization. However, the charging and discharging rate of electric vehicle power batteries is small, and the charging time is strictly limited. The battery is often under charged or overcharged, which destroys the internal structure of the battery in the long run and greatly shortens the service life of the battery. In practical application, many batteries are not used but charged, which virtually increases the use cost of electric vehicles and is not conducive to the mass production and promotion of electric vehicles. Therefore, based on the principle and technology of energy storage, this paper studies and analyzes the optimization of battery CE of NEV.

Domestic and foreign scholars have analyzed the optimization of battery charging efficiency of new energy vehicles based on energy storage principles and technologies. Kim j et al. Proposed a problem specific optimization method, which can solve the optimal control problem of charging pulse and sliding state with less computing resources than the general optimization algorithm. This rapid optimization is possible because the algorithm utilizes specific cost structures and problem attributes. It can accelerate the recursive and time-consuming system design or control design process in the research of hybrid electric vehicles [1]. JW a et al. Proposed a robust on-line energy management strategy (roems) for fuel cell hybrid electric vehicles (FCHEV) to deal with uncertain driving cycles. Considering the power loss of fuel cell, battery, motor and brake, the energy consumption model of fuel cell hybrid electric vehicle is established. A method based on off-line linear programming is proposed to generate benchmark solutions [2].

New energy electric vehicles have attracted more and more attention because of their low energy consumption and no pollution. With the increasingly mature power grid structure and electric vehicle technology in China, the development of electric vehicles will be better and better. But now the bottleneck restricting the development of electric vehicles is the energy storage device of electric vehicles. As the power supply device of electric vehicles, the development of power batteries is very important. However, due to the improper charging method, the batteries on the market are often scrapped before reaching the theoretical charging times. In this paper, the optimization strategy of CE of new energy electric vehicle battery is studied. This paper introduces the system structure of electric vehicle and the working principle and charging characteristics of power battery. The main parameters of the battery are analyzed to provide a theoretical basis for the selection of reasonable and efficient charging methods. Based on the principle and technology of energy storage, combined with the dynamic model of battery, this paper maximizes the CE of battery and improves the CE of NEV [3-4].

2. Energy Storage Principle and Technology and New Energy Vehicle Battery

2.1. Structure of NEV

Electric drive system is the most important system of the whole vehicle, and it is also the biggest difference from fuel vehicles. Drive the car, and control the regenerative braking of the car when it slows down or goes downhill.

The part designed in this paper is the charging system in the power supply system. Charging system is now the bottleneck of the development of electric vehicles. In order to meet the requirements of vehicle power performance and driving range, the basic performance of electric vehicle power battery is high specific energy. In addition, the power battery should be able to charge and discharge repeatedly for many times, with high efficiency and no pollution. At present, power nickel metal hydride battery has become a development trend of power battery because of its high energy density, light weight, convenient carrying, long cycle life and other advantages. The energy management system is mainly responsible for the management of the energy utilization of the power battery, the real-time feedback of the voltage, current and temperature during the charging process, and the generation of feedback signals through the analysis and comparison of the above data to manage the supply of energy from the motor to the power battery [5-6].

2.2.Energy Storage Principle and Technology

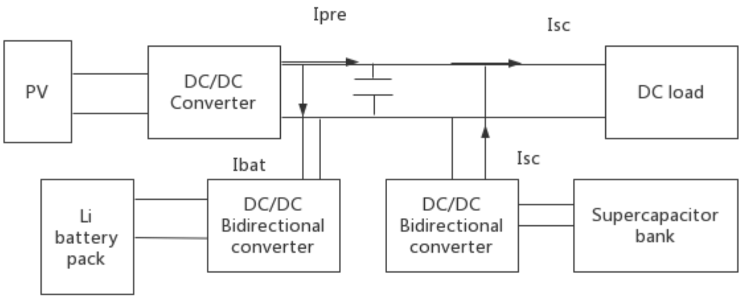

Figure 1. Structure diagram of hybrid EST

The structure diagram of DC based hybrid EST is shown in Figure 1. According to the law of conservation of energy, the power of the load is:

$$p_{load} = p_{bat} + p_{sc} + p_{pv} \tag{1}$$

According to the structure diagram, the hybrid EST is applied to the microgrid under DC operation. When there is fluctuating power in the microgrid, the battery is used to respond to the low-frequency component of fluctuating power, while the high-frequency component is quickly responded by the super capacitor in the system[7]. By comparing the collected DC Bus Voltage VDC with the given vdcref, and then according to the charging and discharging current IBAT of the battery, controller 1 realizes the operation of the bidirectional converter DC-DC in the voltage stabilizing mode, and the principle of controller 3 is like that of controller 1. The high-frequency component of the fluctuating power detected by the high-frequency filter is used as the feed point power pscref of the super capacitor. The controller 2 controls the power of the super capacitor by controlling the current of the super capacitor according to the collected super capacitor voltage and charge discharge current. When the battery is over discharged, the controller 4 acts to charge the battery with constant voltage and current limit [8-9].

When the load changes suddenly, the high-frequency component of fluctuating power is detected by high pass filter. The expression of high pass filter is given by equation (2):

$$\frac{p_{scref}(r)}{p_{load}(r)} = \frac{hr}{r + v_0} \tag{2}$$

Where pscref is a given amount of fluctuating power, γ Is the efficiency of bidirectional converter. When the fluctuating power increases suddenly, the super capacitor power and discharge current are:

$$\begin{aligned} p_{sc} &= w_{sc} l_{sc} = \frac{p_{scref}}{\gamma} \\ l_{sc} &= \frac{p_{scref}}{w_{sc}\gamma} \end{aligned} \tag{3}$$

In the above formula, the terminal voltage of the super capacitor is WSC, and its current is LSC. When the fluctuating power decreases suddenly, the power absorbed by the super capacitor and the charging current are:

$$p_{sc} = w_{sc} l_{sc} = p_{scref}\gamma$$
$$lsc = \frac{p_{scref}\gamma}{w_{sc}} \quad (4)$$

Therefore, from equations (3) and (4), the power of the super capacitor can be controlled by the charging and discharging current of the super capacitor. DC based hybrid EST is conducive to the optimization of CE of NEV.

2.3. Power Battery Model

There are thousands of battery packs in the battery pack to provide power for the car, which is similar to the fact that there are many people who need management, and the battery packs also need management to better show their performance. However, managing these battery packs is not a simple problem [10-11].

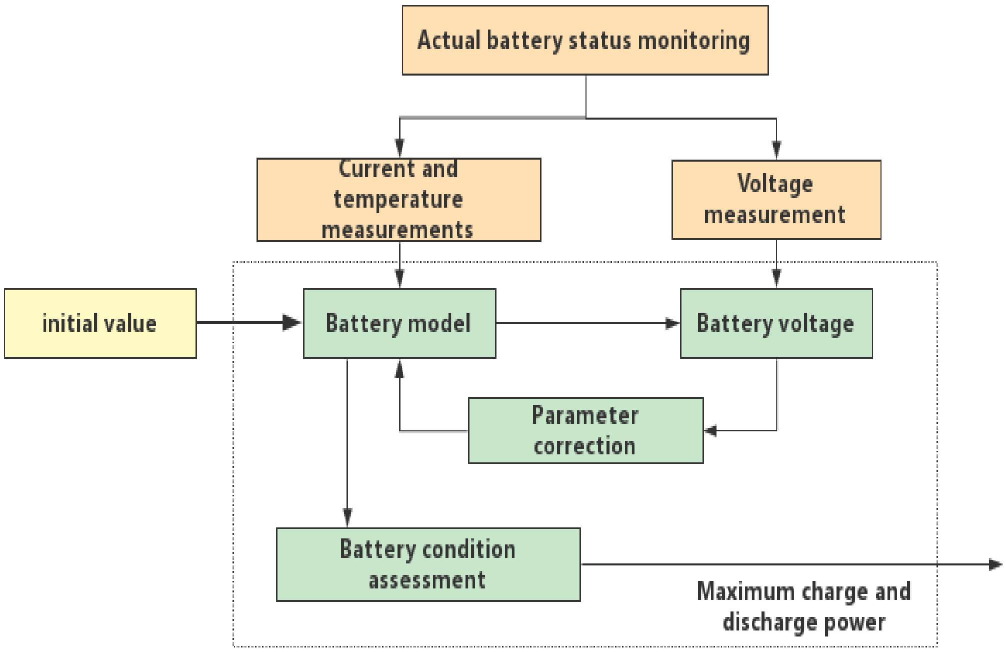

Figure 2. Battery model function

Figure 2 shows the function of the battery model. Lithium battery has electrochemical and nonlinear characteristics, and only the battery terminal voltage and load current can be obtained directly. Therefore, the required battery model should be able to accurately reflect the working characteristics of the battery, as shown in Figure 3. From the perspective of control, they belong to white box model, gray box model and black box model respectively [12-13].

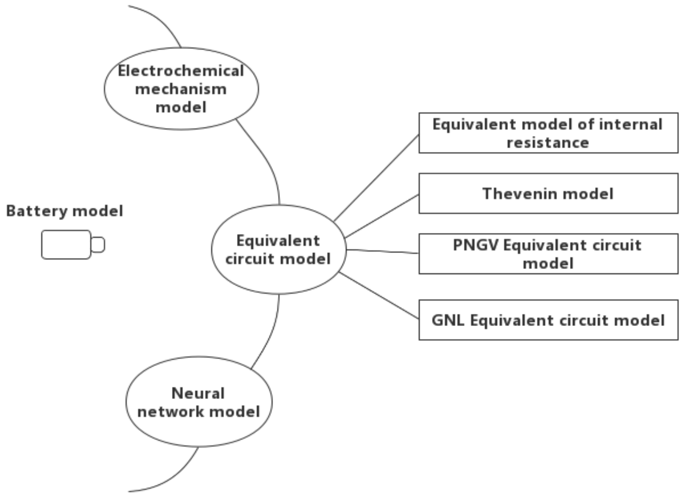

Figure 3. Battery model classification

2.3.1 Basic Structure of Lithium Ion Battery

The main structure of lithium-ion battery includes four parts: positive material, negative material, electrolyte and diaphragm. The ability of the cathode material to insert and remove lithium ions also affects the performance of the battery. The electrolyte is usually a colorless and transparent liquid with strong hygroscopicity, and ethylene carbonate, propylene carbonate, etc. are often used [14-15].

2.3.2. Working Principle of Lithium Ion Battery

The positive and negative electrode electrochemical reaction equation and total reaction equation of lithium-ion battery during charging and discharging are respectively (taking lithium iron phosphate power battery as an example):

Positive reaction: $LiFePO_4 = xLi^+ + xe^- + Li_{(1-x)}FePO_4$

Negative reaction: $6C + xLi^+ + xe^- = Li_xC_6$

Total battery reaction: $LiFePO_4 + 6C = Li_{(1-x)}FePO_4 + Li_xC_6$

3. Optimization of Battery CE of NEV based on Energy Storage Principle and Technology

3.1. Design of Optimal Control Strategy for CE of NEV

The output power of the system is related to the fundamental frequency amplitude of the output voltage of the inverter at the transmitting end, the fundamental frequency amplitude of the output voltage of the resonant circuit at the receiving end and the coupling factor between the coils. The movement of the coil at the receiving end will cause the change of the coupling factor, reduce the power output of the system and even affect the efficiency of the system. The power output of the system can be controlled through the circuit, Therefore, by analyzing the principle and technology of energy storage, controlling the charging power can improve the power output of the system and improve the working efficiency of the system [16-17]. Firstly, the dc/dc circuit is modeled and analyzed in detail, then the PI controller is designed to ensure the stable output of the system, and then the power control strategy is formulated according to the energy storage principle and technology to optimize the system efficiency.

3.2. Modeling and Analysis of Dc/Dc Circuit System

Average equation of state modeling: when modeling and analyzing the buck circuit at the receiving end, IR current is regarded as interference. When the switch tube of the circuit is on and working, the working state equation of the switch tube on and off is averaged to obtain its working state, as shown in formula (5).

$$\begin{cases} C_2\dfrac{bU_{bc}}{bt} = I_r - b\times I_S \\ S\dfrac{bI_S}{bt} = b\times U_{bc} - U_{out} \\ C_3\dfrac{bU_{out}}{bt} = I_S - \dfrac{U_{out}}{R} \end{cases} \tag{5}$$

Where, B is the duty cycle control signal.

Optimization strategy of battery CE of NEV based on energy storage principle and technology when the receiving coil at the receiving end of the charging device moves, the coupling factor between the coils will change, which will affect the charging power and CE. Therefore, the principle and technology of timely processing energy storage is the basis for charging power control and efficiency improvement of charging equipment [18]. According to the energy storage principle and technical algorithm discussed above, we can get:

$$g = \frac{Pv_0 L_{f1} L_{f2}}{U_{AB} U_{ab}\sqrt{L_1 L_2}} \tag{6}$$

In formula (6), V0, LF1, LF2, UAB, L1 and L2 are fixed values, and the EST G is directly proportional to the power P and inversely proportional to the output voltage UAB of the resonant circuit. Therefore, the change of coupling factor can be tracked by observing the values of P and UAB, so as to carry out corresponding power control to improve efficiency.

4. Experimental Test Analysis

The goal of this paper is to design a control algorithm to improve the efficiency on the premise of ensuring the maximum transmission power. The higher the working power is, the higher the CE is. Theoretically, the maximum charging power and CE can be obtained by keeping the rated power of the system 1kW during the movement of the receiving coil at the receiving end, that is, when the coupling factor of coil movement is reduced, the charging power can be kept unchanged by controlling dc/dc to increase UAB. However, due to the limitation of the rated voltage value of switches, capacitors and other components, UAB cannot increase indefinitely. Therefore, in order to obtain sufficient transmission power and CE and ensure that the value of UAB will not be too large, the method of combining constant power control and constant voltage control of UAB must be adopted when the receiving coil moves.

Figure 4 and figure 5 are the comparison curves of power and efficiency theoretical calculation using the efficiency optimization control strategy and the non optimization control strategy. The abscissa is the alignment position of the coil at the transmitting end and the coil at the receiving end, and the ordinate is the power and efficiency respectively. In the figure, curve a represents the theoretical calculation curve 46 of the system power efficiency when the dc/dc switch is constantly on, and curve B represents the power efficiency curve when the efficiency optimization control strategy is used.

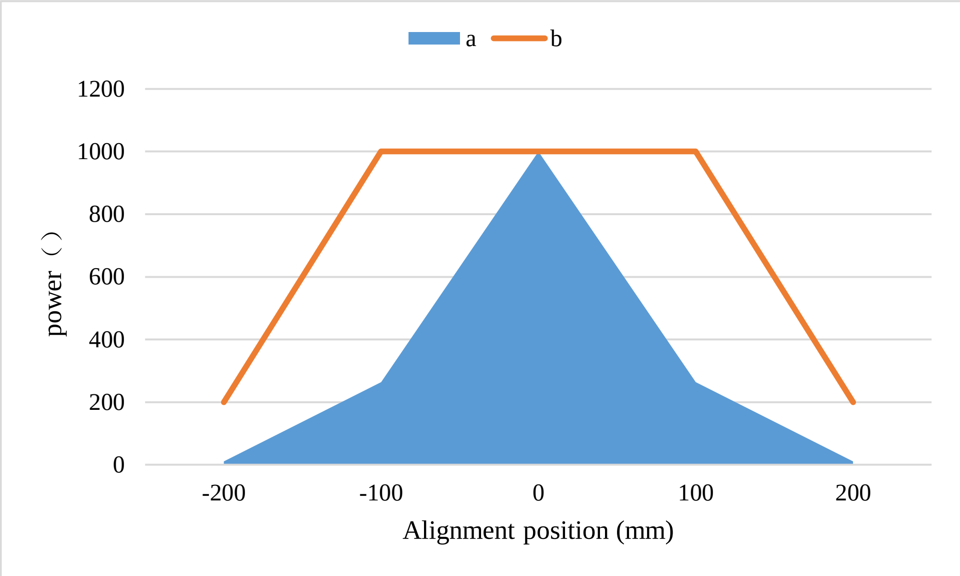

Figure 4. Power

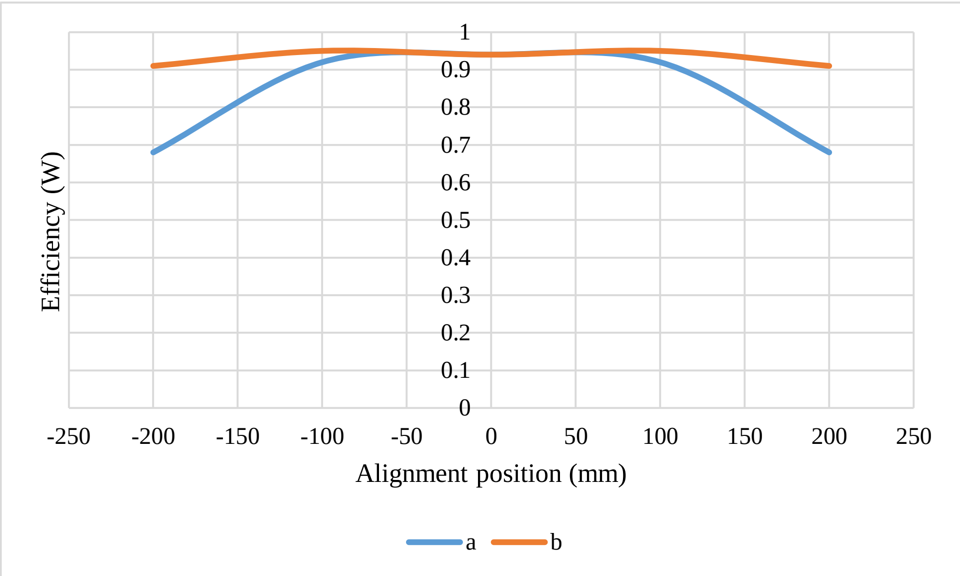

Figure 5. Efficiency

Through comparison, it can be seen that the efficiency power calculated by using the optimal control theory is significantly greater than that without control, especially when the coupling factor is small. The average efficiency of dc/dc without control is calculated to be 92.8%. The average efficiency of DC / DC with efficiency optimization control strategy is 93.8%. During the period when the secondary coil moves from the first alignment position to the alignment position with the second transmitter coil, the average power of DC / DC with efficiency optimization control strategy is 787.2w, which is higher than the average power of 431.1w without control.

5. Conclusion

The research on the charging optimization strategy of new energy vehicle power battery is a hot research topic, which has attracted the attention of countries all over the world. Based on the principle and technology of energy storage, this paper has optimized the CE of new energy vehicle batteries, and achieved good results, but there are also shortcomings, and there are still many work to be further improved and improved: there are many key technologies to be further improved and developed. Due to the limited experimental conditions, the charging methods and charging devices proposed in this paper have not been really investigated in electric vehicles. At present, the electric vehicle industry is still in the initial stage of development, and the charging infrastructure is in the initial stage at home and abroad. It is difficult to obtain the data of electric vehicles and charging stations. The expansion of the scope makes the optimization of CE of the energy storage principle and technology proposed in this paper unable to be processed quickly. Therefore, the charging system of new energy electric vehicles in a wider range can be studied later, which will bring better convenience to electric vehicle users. Improve CE.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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