Research on Energy Management of HEV Lithium ion Battery

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Abstract *Battery system is a more complicate and fragile link in the HEV vehicle. The performance of battery system directly affects the whole Energy and the function and cost of HEV system. Therefore, energy management of battery system can optimize the working state of battery and make it match better with other system. The paper mainly discusses the charging management of Lithium ion battery and energy feedback of braking. Results of experiment demonstrate the proposed energy management strategy has an obvious effect of saving energy and can reduce the charging time and improve efficiency.*

Keywords *Energy Management HEV lithium ion battery Energy feedback of braking*

1. Introduction

With the rapid development of automobile industry, energy and environmental issues become even more acute. In order to solve the energy consumption and pollution caused by these two problems, hybrid electric vehicle (HEV) has been rapid development [1]. Storage battery can store and provide clean power, and has been widely used in hybrid electric vehicles. Compared to other batteries, lithium ion battery [2] has many advantages, such as the high voltage, energy density, no memory effect and the long lifetime. Although battery technology has been great progress, traditional methods such as constant voltage battery charging method, constant current method, phase-wise constant current method and the constant current - constant voltage method [3] have some problems, such as charging too long, and seriousness of polarization effects, reduced cycle life of the battery, taking noting of energy feedback during the period of braking into account, so it is necessary for new battery fast charging technology [4]and new method of energy feedback during the period of braking.

According to Maas Laws [5], to charge the battery fast, the charge current should comply with the optimal acceptable current curve, which is a negative exponential curve. In practice, it is very difficult to meet the requirement. Common methods such as fast charging pulse charge method [6], intermittent charging method [7], achieve fast-charging by eliminating the polarization effects [8]. Pulse charging method is an effective method of fast charging. But, it is difficult to determine frequency of pulse [9]. In this paper, the pulse charging method is adapted, using variable frequency pulse charge method to reduce the charge time and improve charging efficiency.

There is a transient and frequent braking in the process of HEV vehicle's driving. It will offer much motive to vehicle if the inertia energy be accumulated. The paper will research how to recycle the maximum possible feedback braking energy without destroying the battery.

2. Principles of Variable Frequency Pulse Charge Method and Description of Algorithm

2.1 Principles of variable frequency Pulse Charge Method

In accordance with the battery EMF equivalent model [10], the resistance of the battery has three parts: ohmic resistence R_{Ω}, electrochemical polarization resistance Z_d and concentration polarization resistance Z_k, the total resistance is as follows:

$$Z_B = R_{\Omega} + Z_d + Z_k \tag{1}$$

The less the Z_B is, the less chemical energy converted from the electrical energy is. So in order to reduce the energy loss during charging, it is necessary to determine the optimal frequency f_{op} of charging to reduce the battery impedance Z_B. The battery resistance changes as the battery SOC, so the charge frequency varies with the SOC. To find the optimal pulse frequency conveniently, we need to charge the battery with different frequencies of pulses, acquire the corresponding average currents, and then select the pulse frequency with maximum average current as the best pulse frequency.

2.2 Algorithm Description

The charging of lithium-ion battery continues with a constant period T_{sum}. A cycle of T_{sum} can be divided into three time sub-periods: T_{full} for fullness detection, T_{seek} for determining of the optimal frequency and T_{ch} for charging. According to experimental results, T_{sum} is set as 5min. The charging process is repeated until the charging completed. T_{ch} f should be much higher than T_{full} + T_{seek}.

Work model of variable Frequency pulse charging as shown in Fig. 1.

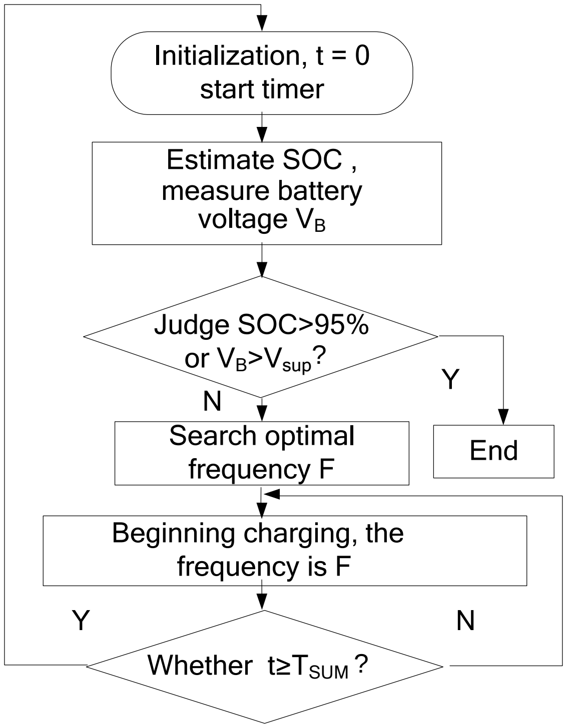

Fig. 1 Work model of variable Frequency pulse charging

The optimal frequency is determined as follows:

1) Calculate the average charging current with frequency f_n. If the m-th sampling value of current is $D_{ib,n}(m)$, and the sum of the sampled currents id $D_{acc}(n)$,and sample value, sample design and for the currents, setting the initial = 0:

$$D_{acc}(n) = D_{acc}(n) + D_{ib,n}(m)\,; \qquad \text{m=m+1} \tag{2}$$

After calculating the average current of M sub-samples:

$$D_{avg}(n) = \frac{D_{acc}(n)}{M} \tag{3}$$

2) Calculating the average current of sampling value of current at varied frequencies, n=n+1.

$$D_{avg}(n) = \frac{1}{M}\sum_{m=1}^{M} D_{ib,n}(m) \qquad n = 1,2,3\ldots N \tag{4}$$

3) Determining optimal frequency according to (5):

$$f_{op} = \left\{ f_n \mid MAX(D_{avg}(n)), n = 1,2,\ldots N \right\} \tag{5}$$

3. Battery Group Charge Management with Energy Braking Energy

3.1 Determination Feedback Current and Braking Time

According to Mass' Law, in the charging process, the maximum acceptable charging current could be expressed as Equation(6):

$$i_t = I_t * e^{-\beta t} \tag{6}$$

Charge the lithium-ion battery which had released capacity C_o with $I_{c\max}$ under the Constant-current charging mode, Δt later, the battery's voltage reaches the charging final voltage V_S, then $I_{c\max}$ is the maximum acceptable charging current, and V_S could be found in the Battery instruction manual of manufacturer. Δt is determined as following:

There are two factors: one is whether it influences the battery's cycle life or not when charging battery with a high current in Δt, the other is considering the durable time of peak power rate. We choose Δt =2min, considering the braking time of 510 bus in Wuhan are mostly within 2minutes.

3.2 Braking Energy Feedback Charging Strategy

First of all, we should judge battery's charge final voltage. If battery's voltage does not reach it, then detection feedback current I_r, and the maximum acceptable charging current was $I_{c\max 0}$ in the brake moment. Under the circumstance of $I_r < I_{c\max 0}$, the braking energy could be feedback. When clock the braking time Δt_r, if $\Delta t_r < \Delta t$ and $I_r < I_{c\max 0}$, start energy feedback; With the continuous braking, energy feedback stop if $\Delta t_r > \Delta t$ or $I_r > I_{c\max 0}$.

Strategy implementation process shown in Fig. 2

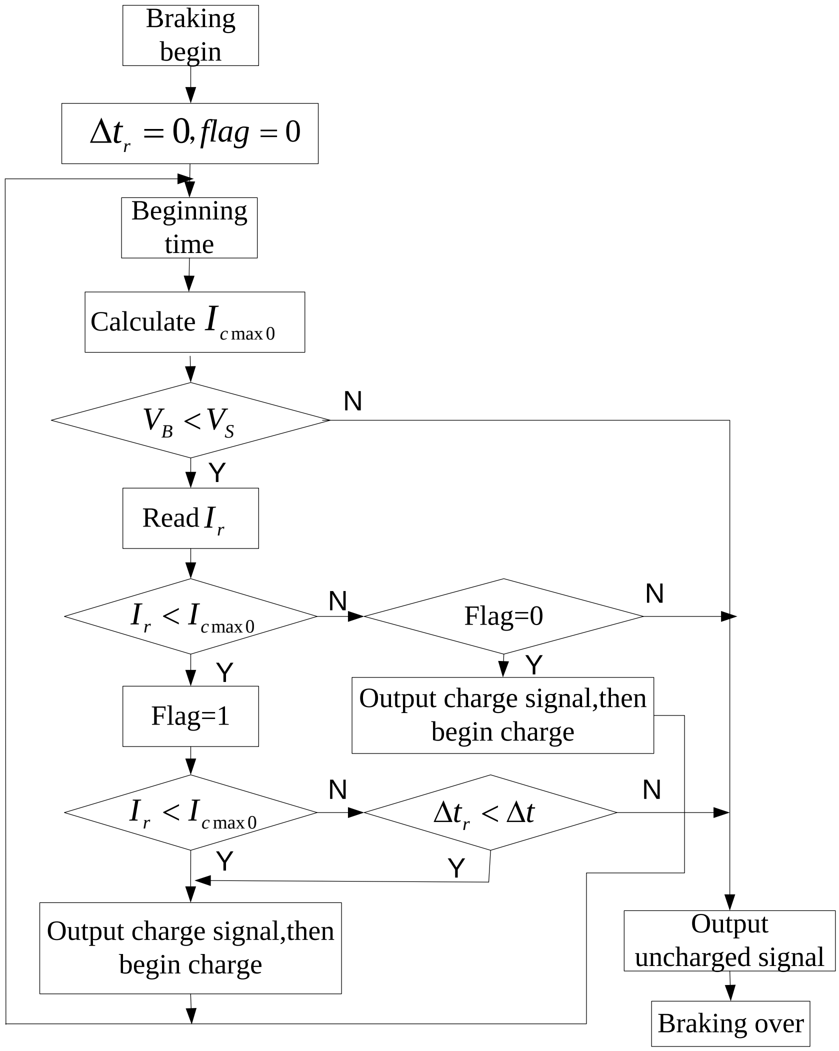

Fig. 2 Flowchart of braking feedback charging current

4. Experiments and Conclusions

4.1 Lithium-ion Batteries Variable Frequency Pulse Charging Experiment

Batteries are selected: The GBS-LFMP90AH square lithium-ion batteries are selected for our variable frequency pulse charging experiments, which are produced by Zhejiang Jia-Beth Green Energy Co., Ltd.

Experimental method: the number of sampling value of current at varied frequencies is selected and the T_{sum} is determined for our experiments.

There are 40 frequencies for sampling, which start with f_1=100Hz,…f_n=f_{n-1}+500Hz(n=2,…49). When the cycle T_{sum} is too short or too long, the charging time will be extended. In our experiments, the T_{sum} is 6min.

The results are shown in Fig. 3 and Fig. 4.

Fig 3 shows a charging curve of the optimal frequency.

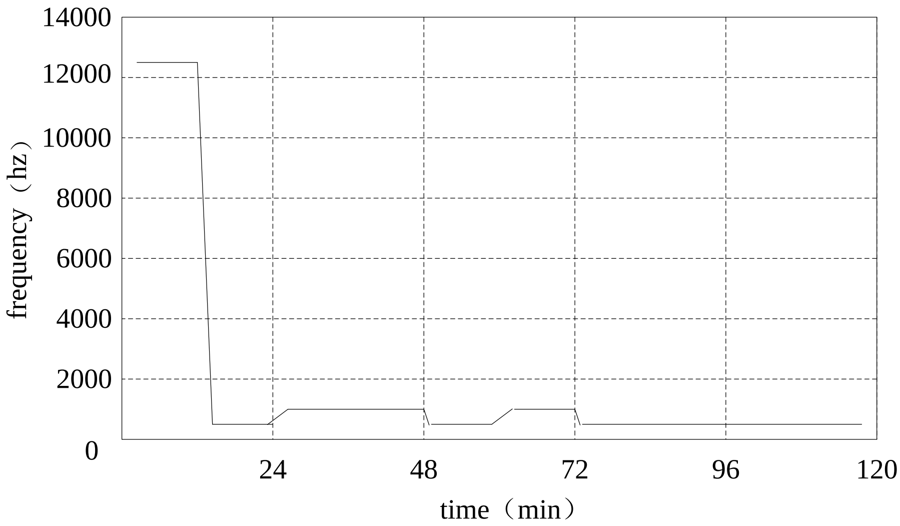

Fig.3 Optimal charging frequency

As shown in Fig. 4, the optimal charge frequency is effected by factors such as SOC(state of charge).

We have charged the batteries using constant current - constant voltage charging method and have charged the same batteries at 1KHZ, 100 KHZ pulse, and then we have charged the same batteries using the method given in this paper. The curves are as follows:

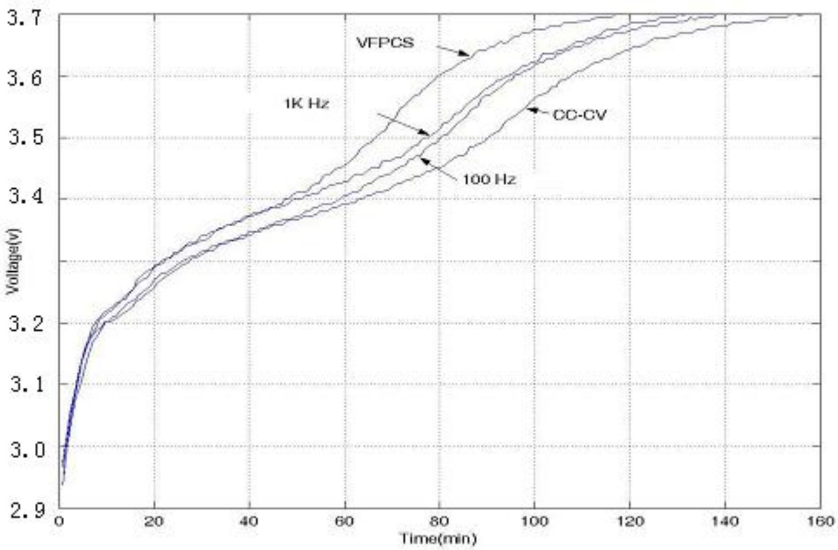

Fig.4 Flowchart of different charging mode

As can be seen from Fig4, the Voltage/Time curve for variable frequency pulse charging method is steeper than those for other methods, implies that it requires less time for charging.

4.2 Comparative Experiment of Energy Feedback

We have a experiment using Dongfeng's 1500kg HEV, the friction coefficient: f = 0.02, frontal area: A = 2.872m * m, drag coefficient: Cd = 0.4. The experiment data show as Table 1:

Table 1 Comparative table of energy feedback

Parameter	Some feedback	All feedback	No feedback
Initial SOC	0.9	0.7	0.8
End SOC	0.87	0.68	0.77
Energy consumer(kwh)	4.52	4.68	4.49
Feedback energy(kwh)	0.31	0.87	0
Energy conservation (%)	6.85	18.58	0

According to Table 1, when in average circulation, while battery's SOC under 0.7, HEV could feedback all of the braking energe, and could saving many energy.

5. Conclusions

At present, the battery management system takes insufficiently the battery energy management into account, or lacks the energy management strategy, thus causes drop of battery's state of health, affects the using and the service life of the battery. In this paper, a fast charging technology for charging pulse is proposed, whose key idea is to accurately determine the pulse frequency and to charge with variable optimal frequency, and a kind of energy feedback strategy is proposed too. Experimental results show that the fast charging technology for charging pulse can significantly shorten the charging time, and can be used in HEV battery management system, the energy feedback strategy can reduce energy's consumption, they can be used in HEV.

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