Control Strategy for Equalizing Charging of Li-ion Power Battery

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Abstract. This paper has proposed a new kind of control method with fuzzy strategy in order to deal with the immanent problem existed in equalizing charge process, with the establishment of mathematical model and parameter tuning. The method mentioned above has included the closed-loop control model of power source controlled by digital pulse-width modulation on the foundation of element simulation in Simulink and conducted the simulation experiments of system response with and without static load-balance, and with prompt load-balance respectively. The result has indicated that the fuzzy controller based on the energy closed-loop control model can solve the severe coupling problem between internal error voltage of the battery and external load current. It can also achieve real-time control output under any error voltage input signal and load current, which improves the adaptability and robustness of the system.

Keywords: Li-ion Power battery; Energy closed-loop; Simulink; Fuzzy control.

1 Introduction

Li-ion power battery has achieved an increasing attention among researchers with its high energy density, high reliability, and environment-friendly quality in recent years[1]. However, because of the discrepancy caused by manufacturing process, battery material, resistance and ambient temperature, it may occur that the voltage of the single battery string in a battery pack is imbalanced, which may reduce or cause a fatal damage to the life of the battery pack in use. So the balance control is of great significance and it has practical applications in extending the life of the battery pack as well[2][3].

An inverter equilibrium charger based on MOSFET is a severe non-linear and complicated system determined by its topology structure, which deduced that the establishment of mathematical model of the system is difficult[4]. It may cost time and is low in profit if the experiment to test the electrical parameters of the system is conducted directly on the device[5][6]. In view of this, this paper has proposed an equilibrium control strategy, which deals the complicated equilibrium control problem of the battery pack as the fuzzy control of energy closed-loop control model.

2 Design of equilibrium controller

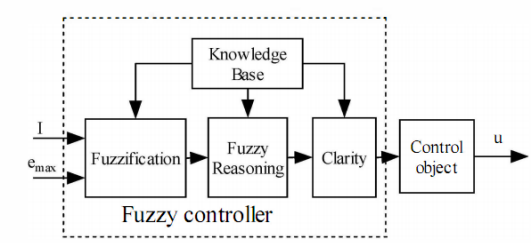

Fig. 1. The complicated equilibrium control problem of the battery pack can be simplified to a dual-input and single-output control. This paper has introduced the energy closed-loop control model based on fuzzy control strategy controller.

Here, T-S deterministic fuzzy reasoning is applied, the rule of which is:
If E is E_i and I is I_j then U is U_{ij}.

Where, U_{ij} is the function determined or real numbers determined, rather than fuzzy sets. Fuzzy control rules are set which refers to the actual equilibrium data, and duty cycle of power-switch drive signal can be obtained according to the reference voltage error value and load current. In the representation of the load current fuzzy domain, N represents that the battery pack is charging; P represents that the battery pack is discharging. Table 1 has indicated the Li-ion power battery fuzzy control output with and without loads. The output is the specific duty cycle value within the range [0, 0.45], the duty of which can be directly used to control the power switch pipe of half-bridge circuit after the traditional PID controller conditioning.

Table 1. The output rule of fuzzy controller

U	I						
E_{max}	NB	NM	NS	ZE	PS	PM	PB
NB	0.45	0.37	0.29	0.15	0.22	0.30	0.34
NS	0.35	0.28	0.22	0.10	0.16	0.22	0.30
ZE	0	0	0	0	0	0	0
PS	0.35	0.28	0.22	0.10	0.16	0.22	0.30
PB	0.45	0.37	0.29	0.15	0.22	0.30	0.34

3 Design of equilibrium controller

3.1 The model of main equilibrium circuit model

The equilibrium circuit simulation model is established with the function components modules in Sim Power System, as is shown in Figure 3. Battery

equilibrium circuit is powered by the equilibrium battery pack itself. The initial DC source can be transformed into required voltage and current through the half-bridge inverter circuit and multi-output transformer for isolation voltage transformation, into eight-way electrical isolation side-way circuit for secondary rectification, filtering.

3.2 Simulation mode of power battery pack

Li-ion power battery pack is composed of many single batteries through the series, and the parallel combination. The internal electrical characteristics are extremely complex, which cannot be completely described for all of its electrical accurately with existing simulation module in SIMULINK. Thus, according to the charging and discharging curves of the known Li-ion battery pack, through the preparation of the S function modules, to simulate battery charging and discharging characteristics of the pack, in order to achieve the simulation of the Li-ion battery pack.

4 Analysis and simulation experiment

During the simulation, first the paper conducted experiment of fuzzy controller for simulation response under static, non-load and variable voltage error control situation. Voltage error output curve of fuzzy controller in real-time control of the no-load condition is shown in Figure 4. The simulation interval is selected for 30min, and use phase-shift Sine function to simulate the max equilibrium degree parameter E. The sine function parameters are set as: amplitude is 0.4, frequency is 0.07rad/min, and the phase angle is 45 degrees, the control output is the duty cycle signal.

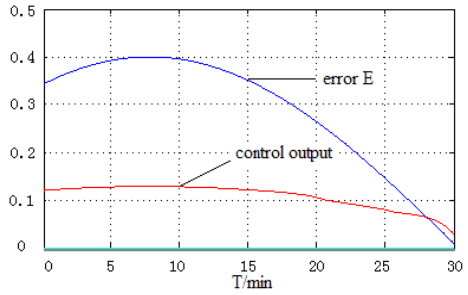

Fig. 2. Control output under no-load condition, it has indicated that, in initial phase of equilibrium control, for a given E, the duty cycle signal will be instantaneous given by fuzzy controller. When E gradually increased, the output duty cycle signal value from the fuzzy controller increased as well. When E gradually decreased, the duty cycle signal gradually decreased, and finally it reached 0 with E. The results have shown that voltage error value of the specific time, the fuzzy controller would output real-time control unit to track the changes, which reflects the real-time fuzzy controller controlling.

5 Conclusion

Aiming at the severe non-linear complex system of inverter battery equilibrium controller, this paper has applied the half-bridge inverter topology as object, fuzzy control strategy, and Matlab software, Simulink, PowerSystem Blochset to provide the basic modules to establish a simulation model, experiments of static, non-load equilibrium simulation, dynamic, loading, equilibrium simulation, and prompt load equilibrium simulation. The results obtained through simulation experiments have indicated that the modulation of the fuzzy controller has a certain stability and anti-disturbance ability. The proposed energy closed-loop control model principle and the established fuzzy controller is correct, effective, and they can be well applied to a equilibrium control of the Li-ion battery pack.

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