Research on the System of Electric Vehicle Battery Management Strategy

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Abstract. According at the inconsistency problem of a large number of electric vehicle lithium in battery group in series, this paper designed the control strategy of hold open circuit voltage, charge and discharge balance and the end of the interrupt equilibrium. This paper combined with the kinematics sequences estimation method to get the formation of the remaining mileage estimation method based on the Calman filter method of SOC estimation energy consumption. In this paper, the balance of the battery management system is achieved by the design of hardware and software. To test the system by using Matlab/Simpower Systems software, and the test results show that balance control strategy proposed in this paper and the balance of system design can effectively prevent the charge battery discharge phenomenon happened.

Introduction

At present, the low power performance of the battery become the main technical bottlenecks restricting the development of new energy vehicles [1]. The technology of group application and management technology of the battery have a great influence on the external parameters of the battery pack. The inconsistency of the battery pack will eventually lead to the decline of the performance of the battery, affect the available capacity, service life and safety [2].In view of the problem that the application of the battery is not consistent in the application of battery, the battery equalization is an important function of battery management system, battery equalization technology has been brought to the attention of the various manufacturers and research institutes [3]. Therefore, in the case of the power battery performance has not greatly improved, the use of scientific group application technology to control the consistency of power battery, can effectively improve the external parameters of the battery pack, and has a great significance to improve the performance of electric vehicles and the promotion of the market [4]. In addition, estimation of the driving range of electric vehicles, not only can understand the performance of the battery directly, evaluate battery equalization effect, but also can improve the driver's driving experience and promote the promotion of electric vehicles.

Design system overall scheme

Battery pack balancing strategy

Taking into account the premise of the balance effect, the energy consumption and the balance of the system, the paper adopts the active two-way equalization scheme based on the coaxial multi - side winding transformer. As shown in Fig. 1, the scheme is based on the counter - type transformer as the core, the transformer primary side battery set at both ends, each side of a pair of side windings is connected to a single cell, and the energy is transformed between the magnetic field and the electric field, and the energy transfer between the battery and the single cell is realized [5]. When a single cell battery voltage is too high, the excess energy can be transferred to the battery pack by the counter - type transformer; and when the voltage of a single cell battery is too low, it can get the energy from the battery pack by the counter - type transformer.

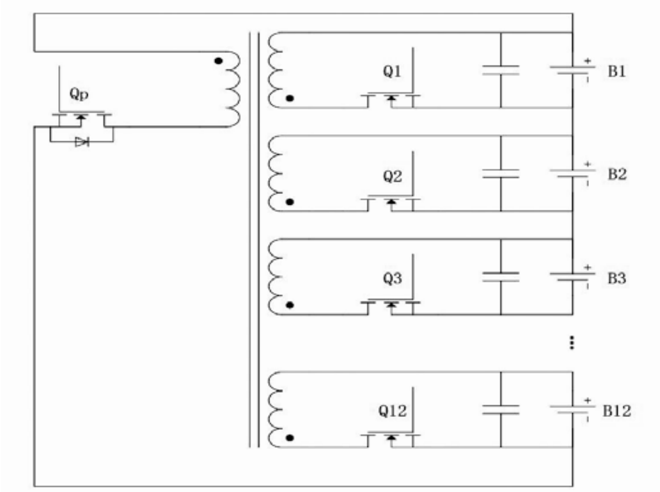

Fig.1 Balanced topology

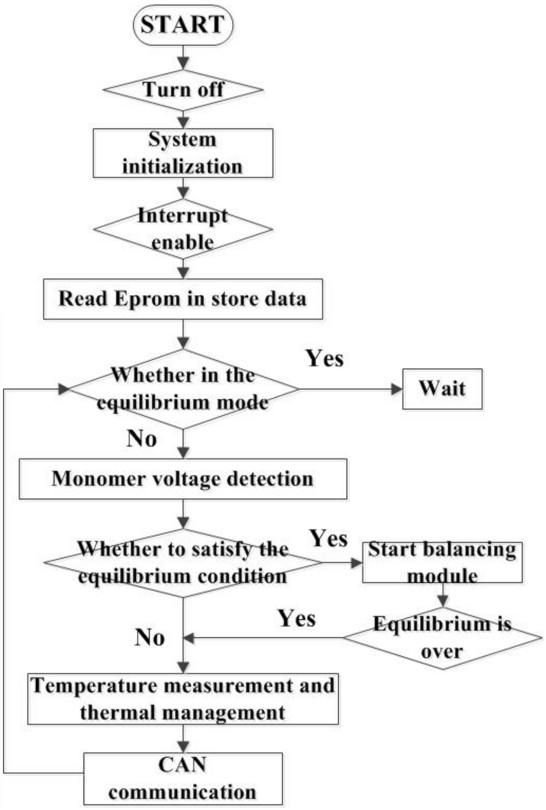

Fig.2 the flow chart of the balanced module

Battery SOC Estimation Algorithm

At present, most of the estimation strategies of SOC in practical applications are using open circuit voltage method and counting method. This article USES the open circuit voltage method and the Kalman filtering method combined to improve the estimation precision of SOC. Specific steps are as follows: The first step, with open circuit voltage method to get the K moments of SOC; The second step, the k+1 time, with the SOC_k as the initial value with the Kalman filter method to make SOC quickly converge to the true value, in the k+1 moments get SOC_{k+1}. The algorithm mainly consists of the following parts:

(1) Use K moments of the state SOC_k and the mean q_k of the process noise, to update the state prior estimate of the battery model $SOC_{k+1|k}$

(2) Through the error covariance matrix P_k and the process noise covariance matrix Q_k of k moment to calculate the Kalman gain matrix K_k.

(3) Calculate the Kalman gain matrix K_k , according to the error covariance matrix $P_{k+1|k}$ and R_k obtained by the second step.

(4) Update the state estimate SOC_{k+1} of the k+1 moment, through Measuring value of working voltage of Li ion battery.

(5) Update the error covariance matrix P_{k+1} of k+1 moment.

The Remaining Driving Range Estimation Algorithm

Referring to the method of calculating the amount of fuel consumed and the fuel consumption of a period of travel, in the estimation of the residual mileage of diesel engine, in the estimation of the remainder of the electric vehicle, the energy consumption rate of the residual energy of the storage battery and the energy consumption of the battery are calculated.

Assuming that the driving characteristics of the electric vehicle are consistent with the driving characteristics of the previous period, then the remaining mileage can be calculated by the formula (1).

$$S = \frac{W}{\Delta W} \times \Delta d \tag{1}$$

Δd is the mileage in statistical time.

ΔW is the energy change in statistical time.

However, setting a fixed schedule time to calculate the remaining mileage has considerable drawbacks. Therefore, the residual can be estimated by using the method of the vehicle's Kinematics fragment as the unit. The calculation of the remaining mileage can be expressed as a formula (2)。

$$S = \frac{W}{\sum_{1}^{K}\left(\Delta W_k\right)} \times \sum_{1}^{K}\left(\Delta d_k\right) \tag{2}$$

W is the remaining energy of the battery;

K is Kinematics fragment number of Statistics;

ΔW_k is the energy change of the K fragment;

Δd_k is the driving range of the K fragment.

In the actual driving process of electric vehicles, it may encounter the situation of frequent start-stop or long time running, at this time, for shorter time segment, the number of fragments is increased by K, and for longer time segment, the number of fragments is reduced by K, so as to ensure that the statistics of the fragment can better reflect the vehicle's driving characteristics.

Realization of equilibrium system

Hardware design of the system

The flyback converter is the core of the equalization module, So, the parameters of the flyback converter including the transformer and the power device are calculated firstly. The rated voltage of the lithium battery is 3.6V, and the voltage range is 3V-4.2V. Each lithium battery group of 12 cells in series, so the input voltage of Uin is 36V-50V, the output voltage of Uo is 3.6V-4.2V. That means if the current is 3A, the output power is 12W, the the work efficiency η is 0.8, the switching frequency f is 20kHz, the switch tube pressure drop V_{ds} is 3V, and the diode voltage drop V_d is 0.8V.

In this paper, we set the maximum duty cycle of the flyback transformer is 48%, the maximum voltage of the switch tube is 100V, the aximum peak current of the MOSFET is 50A. We set the model of the infineon is IPD70N10S3L, and the VDS is 100V, the ID is 70A. With the same method, the model of the side switch is MOSFET IPG20N04S4L-08, and the VDS is 40V, the ID is 20A. We select the MCU chip of PD78F00888 from Renesas 78K0/FC2, 8 series, the chip supports large capacity memory expansion, 8 way timer; multiple serial communication interfaces, including 1 UART(LIN support). The chip contains 1 CSI/UART multiplexing, 1 CAN, 8 channel and 10 A/D conversion, that can meet the control requirements. Based on the idea of modular hardware, the single voltage acquisition circuit scheme is voltage of the photoelectric relay + signal conditioning circuit, +AD converter chip + photo coupler and single chip microcomputer.

The hardware design of battery management system is directly related to the strategy of battery management, at the same time, it affects the performance of control algorithm. So, in this paper we must ensure the accuracy of the data acquisition, the reliability of the system and the reliability of the system. The main control module mainly realizes the functions of current measurement, total voltage and insulation detection, SOC estimation, SOH estimation, relay control, data storage and vehicle communication.

The main control chip of the battery management system is with 32 bit microprocessor PD70F3380 Renesas V850 series. The system power is 24V supply for car. Because of the supply voltage of MCU and CAN transceiver is 5V, it is required to change the 24V voltage into 5V. The system uses CAN transceiver CAN to carry out the TJA050 communication between MCU and power assembly control system and other controllers. This paper use the previous SOC information remain in the data storage module, the open circuit voltage method estimates with the corresponding amendments, and get a more accurate SOC_0. In addition, record the current battery recycling is also conducive to judge the battery health status in order to take timely measures to extend the battery life.

Software design of system

As the single battery SOC estimation is large and the accuracy is not high, and the battery capacity is difficult to measure, so this paper abandons the equilibrium strategy or battery capacity based on SOC to use the single battery voltage as a variable. Equilibrium strategy of the system is composed of three parts: open circuit voltage balancing, charging and discharging end equilibrium and interrupt equilibrium. Its' main program is shown in figure 2.

First, we initialize the various registers and each module of the microcontroller. Then, we read the address of the machine and the number of batteries contained in the battery box from EEPROM. Finally, the program enters the main loop, the program detects the temperature of the battery's voltage and the battery box, and according to the state of the monomer battery and to determine whether to start the voltage balanced module and make the appropriate action and instructions. At last, in order to prevent the program running and entered the cycle of death, the main program also added reset timeout. Control software is designed to use the program structure of "loop + interrupt". That is, in the main loop program in order to execute the subroutine that real-time requirements are low, and in the interrupt service program execution subroutine that real-time requirements are high. Once the trigger condition is satisfied, the corresponding subroutine will be executed immediately, thus ensuring the real-time performance of the control.

Simulation analysis of equilibrium system

Model establishment of equilibrium system

In order to verify the control effect of equilibrium strategy, the simulation model of the equilibrium system is built in Matlab / Simpower Systems environment..In this paper, a proper simplification of the equalization system is included: using the 500F capacitance to replace the lithium ion battery, use of a capacitor instead of the battery in the simulation process, and assuming no polarization voltage and the process of acquiring battery voltage. Then, the voltage change curve is continuous and the multi side winding of the flyback converter is 1 original 4 side edges, and the leakage inductance of the 5 windings is 0, so that the clamp circuit is omitted.

Simulation of equilibrium system

Balanced control strategy includes: open circuit voltage equalization of the process, work in the voltage plateau of the interruption of the balance, the voltage balance of charge and discharge end. The equilibrium function of the circuit is at the top of the equilibrium and the equilibrium of the bottom. Because the energy flow is the opposite of the two, and the two is using the same transformer, therefore, at the same time, only the top or bottom of the balanced equilibrium.

Set the initial value of the voltage as V1=3.7V，V2=4.05V，V3=4V，V4=3.5V. The simulation curves are shown in figure4. In the initial stage, the V4 and V1 are obviously lower than the average voltage, so the bottom balance is triggered. Because the balance of the two is from the battery pack to the monomer battery, so it can be balanced at the same time, No. 1 and No. 4 battery voltage battery increased gradually.

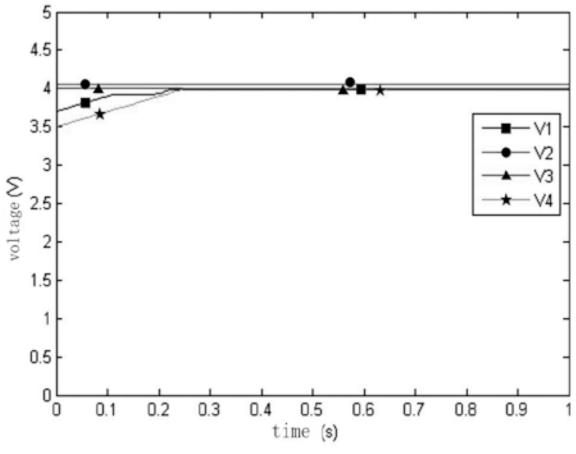

Fig.3 The use of process equilibrium

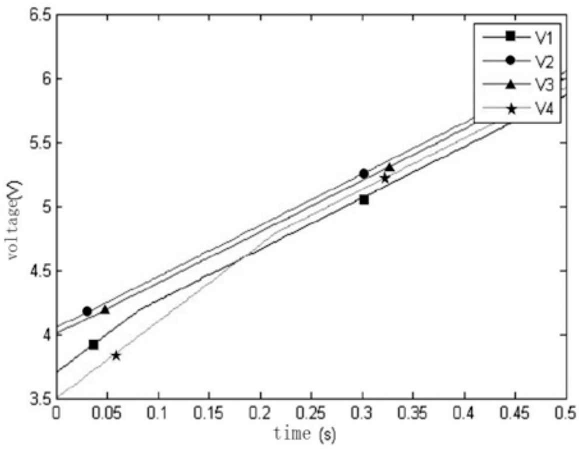

Fig.4 Charging process equilibrium

When the charge is balanced at SOC>90%, the charging terminal is balanced with the top, because of low capacity, internal resistance of the battery is too large resulting in the individual battery during charging voltage rise too fast. Once the voltage is too large, battery charging voltage due to large capacity, the lower internal resistance of the battery DC is not full, therefore, it is necessary to carry on the top equilibrium of the voltage bias. At this point, the top equilibrium could not be carried out again at the bottom of the equilibrium. If the bottom of equilibrium, equilibrium efficiency will be occupied and the system could not fully suppress the rise of the single battery voltage. To carry on the top of the balanced to the high voltage of the battery, energy will flow to the battery pack at both ends, charging for the battery pack.

The discharge end balance will be triggered at SOC<20%, get the bottom of the equilibrium to the low voltage single battery. Batteries with small capacity and high voltage DC resistance will decline at a rapid rate during discharge, then it will reach discharge end voltage and the single battery can be used to waste. Figure 5 is a balanced voltage waveform. V1 and V4 voltage is low, after the opening of the bottom equilibrium, they gradually close to the V2, V3, a period of time after the basic agreement, the discharge time is prolonged.

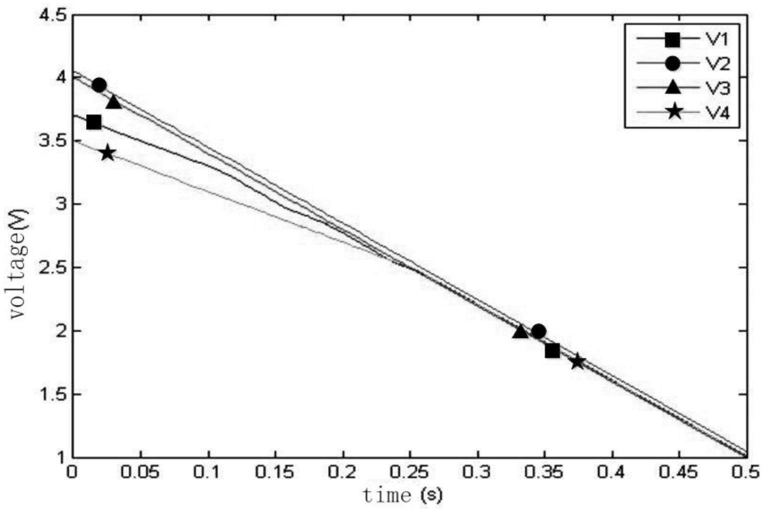

Fig.5 voltage waveforms of equilibrium openning

The remaining mileage estimation simulation

Simulation with ADVISOR under different working conditions, the driving process will be obtained as the real driving condition of the vehicle. Send the vehicle SOC speed information and other data into the remaining miles of electric vehicle mileage estimation algorithm, the estimation results of the remaining mileage can be obtained. Through the analysis of the results and optimization of the parameters of the weighted coefficient of motion segments in the algorithm, In ADVISOR, the simulation parameters are adapted to different vehicle parameters, and the simulation results are obtained.

Set up the cycling condition for 10 times, That is, the depletion of the battery energy SOC is 0. In the simulation, the difference between the driving range of 83.5km and the simulation can be used as the actual mileage. In the simulation, the speed of the vehicle is down along the time and the SOC value is recorded, the falling edge of the vehicle is the vehicle idle, adjacent two idle intervals as a kinematic fragment. At this time, if the speed is not 0, then the above one is at this time for a fragment. Calculate the mileage and the consumption of each fragment. This paper calculates the remaining distance with the latest 5 fragments of data.

As shown in Figure 6, the results of the experiments show that, the actual vehicle speed and driving condition are basically the same. In the United States standard operating conditions, the vehicle runs more than 7 cycles, in close to 10000 seconds, SOC fell to 0. We can see from the rest of the mileage waveform that there are some errors in the estimation of the remaining mileage and the actual mileage, and the error derived from the kinematics of the fragments and the road has a certain difference, SOC estimation errors are included. The estimation error of the residual range of the system is less than 5km.

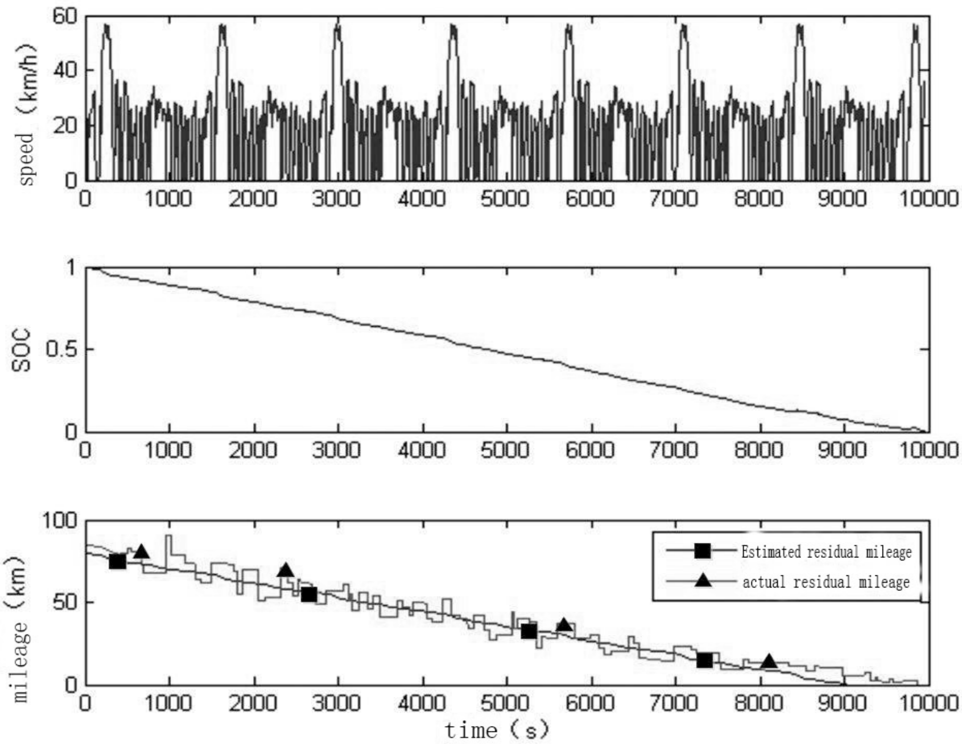

Fig.6 The simulation results

Conclusion

This paper uses the topology of multi winding transformer based on flyback converter to design transformer and power device and make the flyback converter runs in DCM mode. Battery pack to the bottom of the low voltage single battery and the top of the battery pack has been realized. Based on the Kalman filtering method and SOC estimation and combined of microtrips algorithm based on electric vehicles energy consumption, this paper obtains the residual driving range of electric vehicle. Then, the simulation of the battery management system's equilibrium strategy is verified by simulation. However, this paper just chooses the intermittent work mode based on the conventional design criteria, in the follow-up study, we should take the practical lithium ion battery as the load, carry on the work pattern experiment, determine the best working mode.

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