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A Portable Fast Charging Power Supply Design for Lithium Battery Pack with Cell-Capacity-Balancing Method

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Abstract: Cell-capacity-balancing method is the latest technology in Lithium battery management system (BMS).It enables the Li-ion cells fully charged and discharged. The cells can also achieve fast charge with dedicated power supply and have a huge market prospect. In this paper, we analyze the characteristics of the Li-ion cells with cell-capacity-balancing method, and proposed a fast charging scheme. Moreover, this paper compares several design schemes from three aspects of power security, portability and conversion efficiency .And finally designed a 100W constant current charging power with wide voltage output, Thus, the Li-ion cells with cell-capacity-balancing method achieve fast charging.

Keywords: Cell-capacity-balancing method battery management system (BMS) I-Battery Fly-back converter constant current *source*

I. INTRODUCTION

With the development of power lithium battery technology, People are increasingly demanding high speed for Li-ion cells .Although there are many fast charge methods at present[1], The most effective fast charge mode is the combination of high voltage and heavy current. However, this method must be built on the advanced and perfect BMS. The system can quickly shut off the power and stop changing at the moment of each cell fully charged, otherwise it will be easily battery overcharged and cause security accidents.

At present, relatively efficient BMS is the cell-capacity-balancing method.
It Can guarantee each cell fully charged and discharged via the battery cut in and out . In 2010, the team of Pro Yu Wei of SINANO, Chinese Academy of Sciences Institute, put forward a minimum unit[2] for intelligent BMS; In 2011, the team invent an intelligent BMS based on the minimum unit (I-Battery) [3].This system utilize cell-capacity-balancing method and can best use of the Li-ion cells' electricity, even if each battery has big difference in capacity. The Li-ion cells continue charging when a fully charged battery quickly shut out, discharging is also the case. It offers the possibility of security fast charge for Li-ion cells on the basis of the advantages of I-Battery's efficiency and security. In 2013, the team designed an intelligent fast charging method for I-Battery[4]. But after investigation, we found that there was no such device to meet the requirement.

II. ANALYSIS OF THE FAST CHARGE STRATEGY

Cell-capacity-balancing method requires some spare batteries. During charging, the battery which has most capacity is as the backup battery and the other batteries are charged. The spare battery is charged when it does not have the most capacity anymore. This ensures that the battery which has the smallest capacity always in state of charge. The cells terminate charging until each battery is fully charged.

We have a Li-ion cells which utilize I-Battery system, It consist of 18 lithium iron phosphate batteries in series, each battery capacity is 1.1Ah. If all 18 series battery charging and no spare battery, the battery is immediately cut out when it is fully charged and the rest batteries are continuous charging. The cells are fully charged until the last battery is cut out. This requires the charger supply a wide output voltage range, namely, the charger must maintain a constant current between 3V and 65V. Limited by the constant current chip available on the market, such charger is hard to achieve. Even if it can be realized, due to the complexity of the circuit structure and large volume, it can be costly. In fact, when the cells remaining the last six batteries are charging, the battery pack is very close to fully charged. Also if it continues charging, the efficiency will be very low. The test results are as shown in Figure 1. It can be seen that the cells' SOC has exceeded 99% when stop charging at remaining last 6 charging. Therefore, considering these factors, the best choice is 15 batteries are charging and the others are as spare battery. Until only the last six batteries are charging, the cells stop charging in order to short charging time, simple design and low cost. Thus we need to design a power which can maintain 1.7 A constant current in the range of 23-55V, that the cells can be fully charged within 45 minutes. Restricted to withstand voltage of mosfet, the power open-circuit voltage is less than 80V. The power also need 90-250Vac and 50Hz input, high security, small volume, and be portable.

III. ANALYSIS OF DIFFERENT SOURCE

3.1 Select power type

At present the vast majority of constant current source is switching power supply, which uses the transistor as the switch tube and the control of the switch tube conduction and the cut-off time and the switching frequency to control to load current[7].

There are many kinds of switching power supply, according to whether the transformer is used to carry out the power transfer standard classification, DC/DC converter can be divided into two categories of isolation and non isolation type.

Isolated DC/DC converter has large volume and low conversion efficiency due to the isolation device, but it can realize the electrical isolation of the input and output circuits, which can not be used for electric shock hazard.

The non isolated DC/DC converter has the advantages of small volume and high efficiency, and can achieve more than 90%, and the cost is relatively low; the disadvantage is that the input and output are not separated, and the danger of electric shock might occur.

If there is no safety issues, Non isolated type can have a wider range of power supply compared to isolated ones and smaller, more efficiency, lower heat and cheaper. But the non isolated power input and output have no electrical isolation which may lead electric shock and contact far often with the user. So from the perspective of user , we must choose a separate type of switching power supply.

3.2 Selection Circuit Topology

Isolation type switch power supply with fly-back converter, forward transformation converter, push-pull converter, half bridge converter and full bridge structure transformation. The application scope and advantages and disadvantages of each topology of isolated switching power supply are shown in Table 1:

Table 1 the advantages and disadvantages of each topology of isolated switching power supply and its application range

Transformation circuit topology	Applicable power range	advantage	shortcoming
Fly-back	Within a few hundred watts	The circuit is very simple and the cost is very low.	Unidirectional excitation, the utilization rate is low; the big power is very difficult.
Forward	Several hundred watts	The circuit is simple and the cost is low.	Unidirectional excitation, low utilization
push-pull	Several hundred watts	On state loss is small, the driving circuit is simple	Biased magnetic field
half-bridge	Several hundred watts	Two way excitation of the transformer, no bias magnetic problem	The driving circuit is complicated; the reliability is low
Full-bridge	Hundreds of kilowatts	Transformer two-way excitation, it is relatively easy to do a lot of power	The circuit is very complicated, the cost is high, the reliability is low.

As seen above: compared to other types, the fly-back structure circuit is more simple, lower cost, more suitable for the output power in the following switching circuit 200W.

In addition, fly-back transformer has a dual function of transformers and inductors, so the fly-back converter does not require secondary output filtering inductance; compared with other transform, fly-back converter with less number of turns can obtain higher voltage and the output voltage can be higher than the input voltage, but also lower than the input voltage. Therefore you can choose the fly-back converter circuit to design the 100W constant current source [5][6].

IV. DESIGN IDEAS

4.1 Constant current drive chip

According to the power supply type and the DC/DC converter circuit topology ,control chip is selected.

Here, we select Jing Feng Ming Yuan Lin company BP3105 constant current control chip. It is used to 85Vac~264Vac full voltage fly-back isolated constant current power supply. The chip has the following characteristics:

1）By using the primary side feedback mode, the constant current can be realized without the secondary feedback circuit and the compensation circuit;

2）The chip with high accuracy makes the output current accuracy reaches 2%;

3）The internal integration of the chip has multiple protection, including open circuit protection, short-circuit protection, chip over temperature protection, over Voltage protection, under voltage protection and FB short circuit protection;

4）Chip operating current is very low and of low power consumption;.

4.2 Design circuit schematics

Design 100W charging power supply schematic as shown in Figure 1:

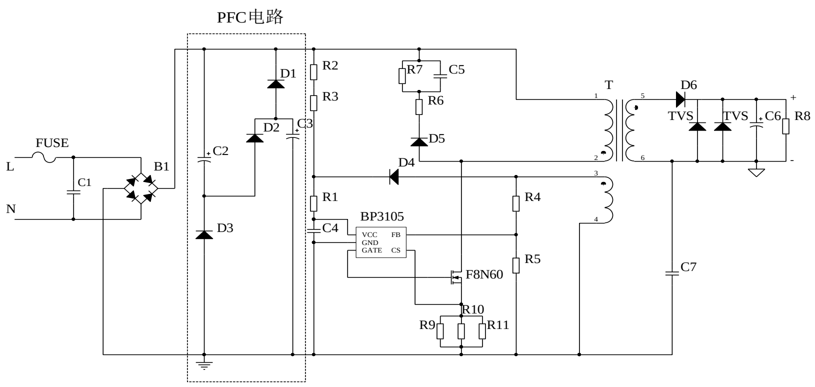

Figure 1. 100W power supply circuit diagram

4.3 Fuse selection

Maximum Power output: 100W; choose 1A, 250V fuse;

4.4 Selection of a safety capacitor

Here we choose the X2 brand 275Vac grade 0.1uF, TENTA safety capacitor and connect it across the power line L-N, used to suppress electromagnetic interference power in order to avoid the electric shock caused by the failure of the capacitor. This kind of structure can withstand the high pressure pulse of 2.5KV.

4.5 Selection of rectifier bridge

Rectifier bridge composes of 4 silicon rectifier tubes, according to the pressure value "rather high not low" principle. We choose to use M7 type rectifier tube which is capable of 1A current and pressure of 700V. .

4.6 Design of PFC circuit

PFC (i.e. power factor correction) circuit is divided into two types: active PFC and passive PFC circuit.At present, most of the active PFC circuits are used, but its circuit structure is complex, the occupied PCB area is big and the cost is relatively high.

A simple passive PFC circuit used here is as shown in figure 1, Instead of using the passive PFC circuit with single capacitor, we choose to use one with three diodes and two capacitors which makes the AC input current smoother, but this low cost PFC circuit also has obvious disadvantages like the DC output voltage is low, and ripple is large, even so ,these shortcomings can be improved at the output end.

4.7 Output current design

The expression of the primary side peak current is:

$$I_{p\text{-}pk}=500 / R_{cs}\,(\text{mA}) \tag{3}$$

Circuit output current calculation method:

$$I_{out} = I_{p\text{-}pk}{}^{*} N_p / 4N_s \qquad (4)$$

Among them, the number of turns of the transformer is the number of turns of the transformer and the peak current of the main stage.

If R_{CS} =0.25Ω，then I_{OUT} =1.5A

If R_{CS} =0.167Ω, (three 0.5Ω resistors are connected in parallel) then I_{OUT} =1.9A

4.8 Selection of feedback resistance

The chip through the FB terminal to feedback the status of the output current, the threshold voltage of FB is set at 1V, the ratio of the upper and the lower pressure resistance of the FB detection is about 4. In order to improve the system efficiency, the feedback detection network on the divider resistance can be designed to 300K ~750K.

Here take: R4=510K , R5=150K ;

R5/R4=510/150=3.4

4.9 Output voltage design

Electrolytic capacitor filter with two parallel 100uF 100V at the output end of the circuit, The output voltage of the power supply is 105V.

Parallel tow 75V TVS tubes at the output, Once the output voltage exceeds 75V, the current increases and the power tube turned off, the power "hiccups", the output voltage is controlled at about 75V.

V. ANALYSIS OF THE TEST DATE

5.1 Testing the load capacity and power efficiency

In both cases, the output current varies with the voltage shown in Figure 2 as follows:

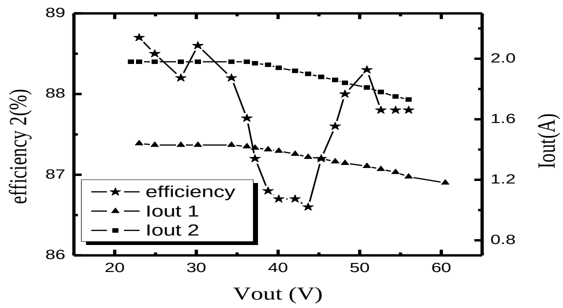

Figure 2 Output current and efficiency changes with output voltage

As can be seen from the figure: When the output voltage between 23V and 55V, power supply remain constant current mode; In the second case,when the output voltage is below 55V, the minimum output current is 1.75A, power efficiency is about 88%, meet the design requirements.

5.2 Testing the No-load voltage and the output ripple

When add a TVS tube at the output end, measured the average no-load output voltage is 74V, the output voltage waveform is shown in Figure 3:

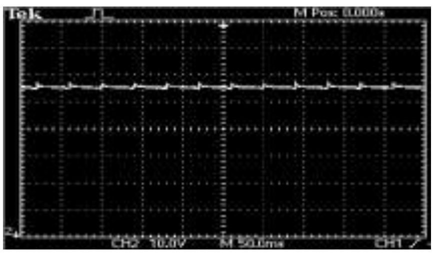

Figure 3. No-load output voltage waveform

In the figure above, each grid represents 10V, as it can be seen, output voltage fluctuation is ±1.5V, meet the design requirements.

5.3 Testing fast charging performance of the power

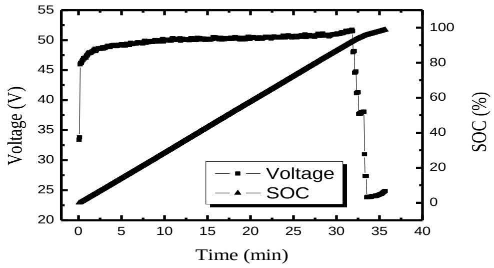

Figure4. the Relationship of charging voltage、SOC and charging time

The performance on fast charging of the Power is shown in Figure 4, when I-Battery system detects there are only six battery in charge, then the system stops charging. Whole charging process lasted 36 minutes, the SOC of the battery pack is more than 99% .

VI. CONCLUSION

This paper analyzes the characteristics of cell-capacity-balancing method of the battery pack, and presents a special constant current fast charge method; Considering the aspects of power supply security , capability and working efficiency. We designed a 100W power supply with a wide range of voltage output and constant current through synthetical consideration, and successfully fast charge the battery pack with cell-capacity-balancing method at last.The power supply we have designed is as shown in Figure 5:

Figure 5 100W power supply

The power supply size is 30 * 28 * 110mm, compared to the isolated constant current source with the same power on the market, our power supply is much smaller.

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