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A Design of Rapid Pulsed Intelligent Charging Circuit

Zhang Lefang*, Li Xiaohong, Ren Zhihong
School of Information Engineering,Xi'an Eurasia University,
Xi'an 710065
*Corresponding author, e-mail: zlf_xa@163.com

Abstract

As known that the traditional DC constant voltage charging equipment not only can cause the battery overcharge or insufficient charging, but also the charging time is too long. In the paper, based on the theory of pulse charging method and the design of the pulsed fast intelligent charging equipment is presented, the implementation of hardware and software process of the system is given out, the analysis of the results show that it can effectively prevent overcharge and low charge phenomenon in the charging process of battery.

Keywords*: intelligent charging, rapid pulsed, circuit, Design*

1. Introduction

With the development of the storage battery, charging technology is keeping updates. The update charging technology not only can meet the requirements of new battery charging, more important is that it can improve the quality of the charging, and prolong the service life of the battery. The traditional charging technology does not adopt the dynamic tracing battery charging current, thus cause the charging time is too long, and cannot meet the need of modern production and living, influence the battery state of technology and service life. Quick charge is to make the actual dynamic battery charging current track the acceptable charging current and the charging current is near to acceptable value from beginning to end. And it can make the battery charge almost under the condition of no gas evolution, thus it can save electricity and keep the battery out of damage. At present, the quick charge application is used more and more widely, especially the pulse type fast charge method has been widely used [1-3].

2. Pulse Charging Theory

Pulse charging method not only can follow the inherent acceptance rate of the battery, and but also it can increase the rate of charging, thus break the limitation of the battery charging curve. It is also the new development of the battery charging theory. In the pulse charging way, first step is to use pulse current in the charging for the battery, and then stop the charging for a short time, then continue to charge. Pulse charging can make battery is full of power, in the break, the chemical combined reaction of oxygen and hydrogen can be absorbed, then the concentration polarization and ohm polarization naturally are eliminated, thus the battery internal pressure is reduced, the process can make the next round of constant-current charging can more smoothly. The battery can absorb much more power and intermittent pulse makes the response time of the battery is long, reduce the output of the gas, and finally improve the battery charging current acceptance rate [4-6].

The principle of pulse charging method is to use break time to make the electrolyte balance thus increase the integrity of the reaction. In the pulse charging method, when the charging is stopped during the charging period, the electrolyte inside the battery can obtain homogeneous diffusion; the energy of the battery can be fully converted into chemical energy, so the charging efficiency is higher compared with the traditional methods. The discharging pulse charging method is followed by a pulse discharge after charging pulse to stop charging for a period of time for charging cycle in the battery charging, and the discharge pulse aims is to eliminate the bubble plate, and reduce the internal resistance, improve the transform efficiency of electrical energy into chemical energy. Since inside the sealed lead-acid battery only just

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added electrolyte, so any form of electrolyte loss will cause the loss of battery capacity, so in the process, the high voltage of the battery can't not be used, in order to avoid the gas of the electrolyte is faster than the speed of gas absorption which is due to excessive voltage [7-11].

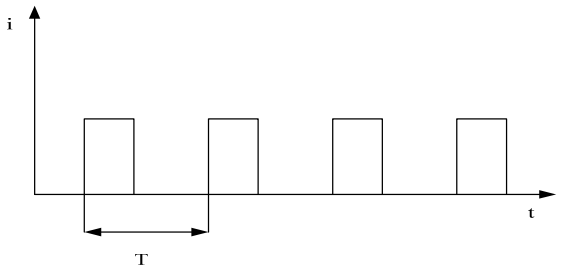


Figure 1. The Pulsed Charging Curve

3. Design of the Pulse Charging Circuit

Charging system is mainly consists of two parts, the main circuit and control circuit, including: input rectifier module, IGBT, high-frequency transformer, rectifier filter circuit, TMS320LF2407DSP, pulse width chip, current sensor, voltage sensor, the comparator switches, temperature switches, DC auxiliary power supply, AC contactor and other parts of the system. The diagram is as shown in Figure 2

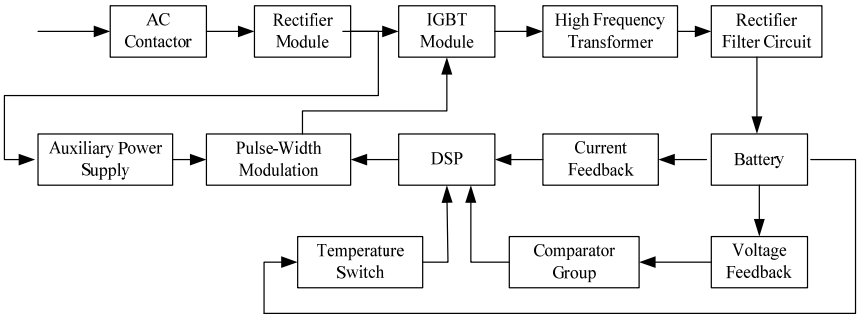


Figure 2. The Diagram of the System

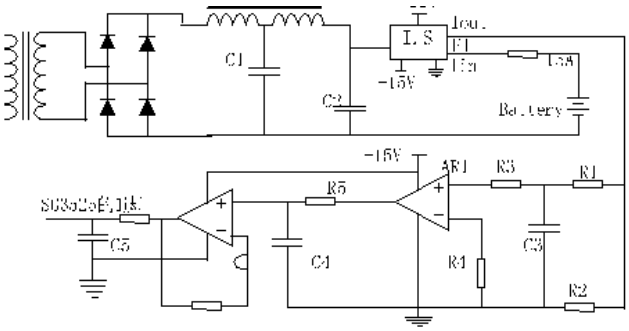
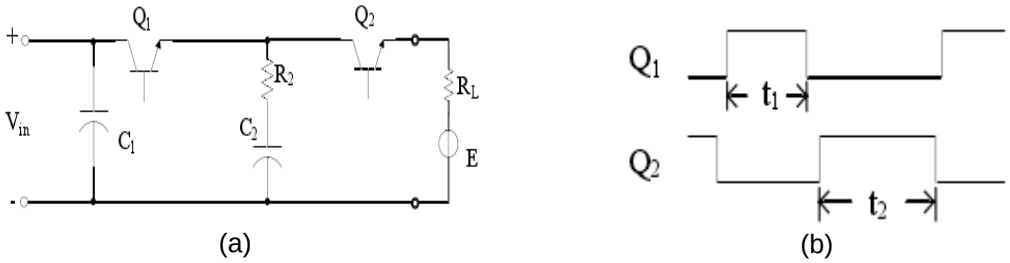


Figure 3. Feedback Circuit of the Current

This device adopts the pulse charging circuit, it is the buck chopper circuit in essential, compared with the basic type of Buck DC - DC circuit, according to the actual requirement, the circuits of practical is worked in the continuous mode, in the design the inductance of the Buck circuit is get rid of, and we increase the power switch on the output side, and form the converter of charge pump type [12-15].

Consider the equivalent series resistance and the parallel resistance effect of equivalent circuits, the constant voltage source and the battery internal resistance in series can be equivalent, the actual structure and switching sequence control circuit is as shown in Figure 4.



(a) (b)

Figure 4. Structure and Time Sequence of Charge Circuit

As mentioned above, in order to eliminate the polarization phenomenon of the VRLA battery charged, and improve the acceptance rate of the battery charge, in the device fast charging method combined with the reflection type charging method are adopted, in the process of pulse charging a certain discharge pulse is added, and then use the fast charging device and the reflection type charging method, the discharge pulse energy is consumed in the end of the parallel resistance, thus cause the waste of energy.

In this device, discharge resistances is removed, and use many energy storage capacitors instead, specific series can be set according to actual need, the fast charging device adopts two levels of energy storage capacitor. Two levels of energy storage capacitor through electronic parallel on both ends of battery in the beginning, its circuit structure are as shown in Figure 5, R3 and R4 are the equivalent resistance of the discharge capacitance circuit.

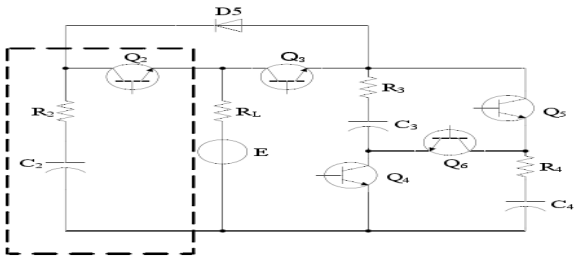


Figure 5. Discharge Energy Feedback Circuit

When the battery need to discharge, the trigger electronic is switched and charge to capacitance, the size of the battery discharge current depends on the capacity of shunt capacitance and parallel series. The discharge current depends on the conduction time of shunt capacitance loop electronic switch, which is controlled by MCU. When the voltage on the external shunt capacitance reaches a certain value, the single-chip microcomputer control electronic switch shunt capacitance connected with string model, and constitute a bootstrap circuit and increase capacitance voltage, and then power is injected to the formal level of energy storage capacitor, the energy recovery of discharge current is realized, and the goal of energy saving is achieved.

4. Charging Power Supply Energy Saving Validation

In the device of the charging circuit, it simplifies the charger switch power supply structure, and new type of charging power structures to remove the high frequency pulse transformer and electronic switches, replace it with optically controlled PWM electronic switch,

thus reduce the number of the energy dissipation element, lead the improvement of the power efficiency, it is a new type of power. In order to verify the battery DC power to get rid of the traditional switch power energy consumption such as the high frequency transformer, the experiment circuit diagram IS as shown in Figure 6, considering the security of experimental requirement etc, this experiment adopts DC 24V input as voltage regulation of PWM.

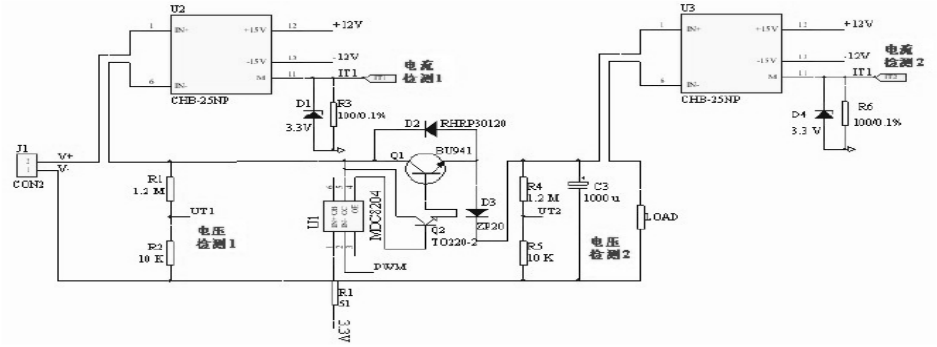


Figure 6. The Schematic Diagram of Energy Transformation

As shown in Figure 6, in a certain test time, the DC 24V power consumption and the consumption of electricity LOAD can be measured, through related comparisons, the energy conversion efficiency of the charging power supply can be obtained, in the actually implementation method, on the parts of UT1 and UT2, we test voltage value, on the parts of IT1 and IT2, the current values are detected, take the time t=10ms as the sampling interval, after the time of 100 consecutive sampling, so the power energy conversion efficiency calculation formula is as (1).

$$\frac{\sum_{i=1}^{100} UT2_i IT2_i}{\sum_{i=1}^{100} UT1_i IT1_i} \quad (1)$$

Adjust frequency of PWM pulse is 200 Hz, the duty-ratio is 8%, the charging voltage is 5 V on both ends of the energy storage capacitor C3, high voltage is 24.8 V, the continuous sampling points are 100 points, the voltage and current can be calculated respectively:

The sum of low-end sampling the voltage and current value of the product:

$$\sum_{i=1}^{100} UT2_i IT2_i = 230000 \quad (2)$$

$$\sum_{i=1}^{100} UT1_i IT1_i = 235600 \quad (3)$$

According to the formula (2), power energy conversion efficiency can be calculated, and it is 97.62%. While the ordinary switch regulated power supply, energy conversion efficiency is only about 85%, even now the soft switch technology of DC/DC converter, its energy conversion efficiency only can reach 90%. In this system, the requirement of the power supply charge and discharge circuit, combined with the thought of energy saving, makes the power of energy conversion efficiency is improved by more than 7.62%, so the device can realize the design goal of saving energy in the new charging power supply.

As shown in Figure 7, the measured waveform in CH1 is the feedback voltage point of waveform measured waveform in CH2 is the driving signal waveform for Q6, the front-end charge voltage is 13.0 V, on the energy storage capacitor C2, when Q6 is connected, the

voltage feedback point voltage is 14.2V, the voltage can recharged to the energy storage capacitor C2. in the conduction cycle of Q6 , the absorption electric energy of C2 is:

$$W_{C2} = \int_{l1}^{l2} u(\varepsilon) i(\varepsilon) d\varepsilon = \int_{l1}^{l2} Cu(\varepsilon) \frac{du(\varepsilon)}{i(\varepsilon)} d\varepsilon$$
$$= C \int_{u(l1)}^{u(l2)} i(\varepsilon) du(\varepsilon) = \frac{1}{2} Cu(t_2)^2 - \frac{1}{2} Cu(t_1)^2 \quad (4)$$
$$= \frac{1}{2} \times 1000 \mu F \times 13.25 \approx 6.63(mW)$$

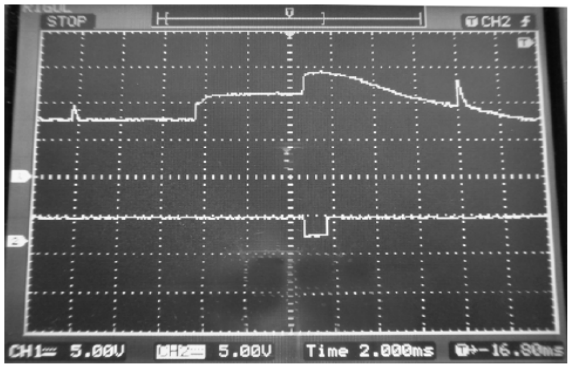


Figure 7. The Waveform of Feedback Voltage and Drive Signal

5 Pulse Charging Voltage Control Strategy

The circuit adopts the voltage feedback control of the pulse fast charging technology, the charging parameters such as pulse frequency, duty cycle can be set flexible, in order to achieve the effect of different stages of charging, so as to achieve the optimal model of quick charging. Through changing electronic switch driven by main controller MCU, the charging pulse frequency and duty ratio effect can be changed.

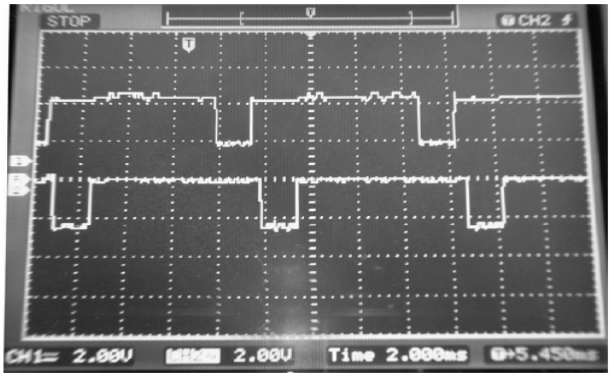


Figure 8. Electronic Switch Drive Signal Timing Waveforms

In the Figure 8, when the drive signal is in low electricity, electronic switch is connected. In order to verify through setting the driving signal of duty ratio can change of the VRLA battery charging voltage and charging current, the circuit is designed as in Figure 9.

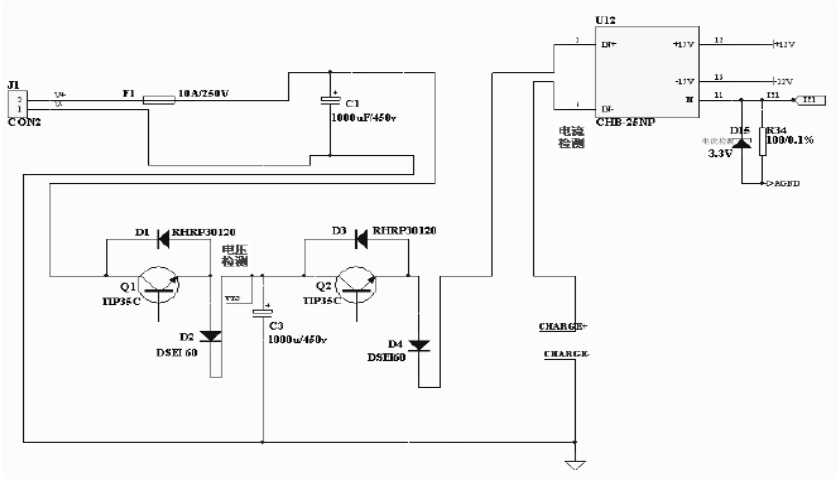


Figure 9.The Circuit of Charging Policy Verification

When the conduction cycle of Q2 and duty cycle are the constant, through adjusting the duty ratio of the Q1, and observe the voltage changes on charging capacitor C3, and the charge of voltage and charging current changes of Q2, so as to verify the feasibility of the fast charging strategies of pulsed control.

As shown in Figure 7, the CHARGE + and CHARGE- are connected to the positive and negative at both ends of the battery, respectively. The filter capacitor C1 is 1000μF, voltage 450V, the power input terminal is access to AC48V and through rectification module KBPC5010 full bridge rectifier, the DC output is obtained, in the energy storage capacitor charging C3, we choose 1000μF and the 450V electrolytic capacitor voltage. The conduction duty ratio of Q2 is 0.8, and we adjust conduction duty cycle of Q1 changes from 0.1 to 0.8, the mean peak voltage at the ends of the charging energy storage capacitor C3 and voltage, and the change of the average charging current flows through the battery can be observed just as shown in Table 1.

Table 1. Charging Policy Verify Experimental Data Table

a	U_{c1m}(V)	U_{c1a}(V)	I_A(A)
0.1	19.2	15.2	0.1
0.2	21.6	15.5	0.4
0.3	26.4	16.7	0.5
0.4	28.4	17.2	1.0
0.5	30.6	17.3	1.2
0.6	31.6	18.5	1.2
0.7	32.8	19.1	1.2
0.8	37.6	22.8	1.2

6. Conclusion

From the study, we can find that the pulsed charging device performance battery is excellent; it can greatly reducing the battery charging time and improve the real-time application performance of the battery. Because the depolarization pulse can eliminate the overcharging of the battery, and effectively ensure the service life of the battery, at the same time we use the front-end rectifier part switch power supply to replace traditional rectifier device, it greatly reduce the volume and weight of the device. Pulsed fast charging device thus greatly reduce its volume and weight of the device, pulse fast charging device developed has a broad application prospect.

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