

# Some Innovative Concepts of Quick Charging

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**ABSTRACT :** Currently, there are many kinds of batteries available for primary or backup power sources. Among them, applications of acid battery and lithium ion battery is one of most important devices due to low cost and continuously improving battery technology. However, a well optimized charging process usually requires a complex control circuitry, such as microprocessors, DSP chips or other power electronics controllers. This paper proposes the methods of quick charging system with , particularly focused on a large size lead-acid battery and lithium ion battery. Accordingly, the charging time can be thus reduced than traditional methods, and the battery temperature can remain no significant change.

## I. INTRODUCTION

Nowadays, the lead-acid battery and lithium ion battery is widely used in a variety of applications such as electric vehicle, uninterruptible power system (UPS), and emergency power supply, etc. However, some drawbacks, e.g., poor energy density characteristics, long charging time, and short lifetime discourage its further commercial applications. Therefore, the development of optimized algorithm to achieve a rapid charging or quick charging and prolong the battery lifetime is still an indispensable research issue in industry

Traditional charge methods either use constant current or constant voltage to charge the battery, or mix these two schemes. However, these methods may suffer from low charge efficiency, over-charge, or long charge time, etc.

Accordingly, a charging method with a negative pulse discharging current was reported [9]–[11]. However, this may cause unnecessary energy consumption and make the charger bulky. In a conventional charger, the well-known two-stage power converter that provides high power factor input and well regulated output exhibits problem such as circuit complexity and high cost. A rapid charger using a single-stage power converter with an energy recovery cell was therefore proposed [12]. This charger can release the stored energy into the batteries during the positive pulse charge period.

Although it can provide high power factor and charging efficiency, a complex control strategy is necessary for performance so that some difficulty may arise to deliver it into a real world. Most recently, a variable frequency pulse charge system (VFPCS) was proposed to improve the battery-charge response [13].

Unfortunately, it was only suitable for small size of battery such as cellular phone charger.

## II. CONCEPT OF NORMAL AND QUICK CHARGING ALGORITHM

Traditional lead acid battery charging modes include: 1.Constant Voltage (CV) charge 2.Constant Current (CC) charge 3.Constant Voltage-Constant Current (CV-CC) charge 4. Pulse charge 5.Positive and Negative Pulse charge. For details, it is described as follows [14-19].

a). Constant voltage charge mode:

The CV mode is the simplest way to charge the battery. Its charging curve is shown in Fig. 1. It can be seen that the charging current decreases gradually when the battery is going toward fully charged status. This method does not push the battery temperature rising significantly, and no over-charge will occur. However, normally it needs a long charging time, and it may be beyond the rated current at the beginning charge stage.

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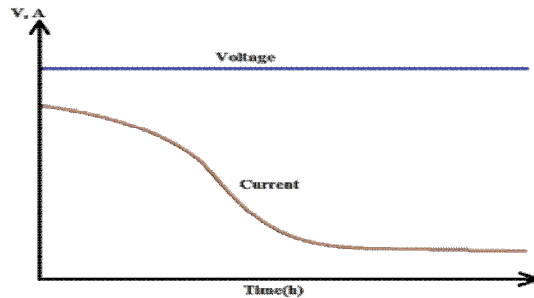


Fig. 1 Charging curve using CV mode

b). Constant current charge mode:

The charging curve using CC is shown in Fig. 2. Based on the CC charge, it is feasible that the charging current can be set under the rated current so that it will not be over the rated limit. On the other hand, the charged voltage will depend on the charging current, and the charge time can be easily estimated. However, the drawback is that it may cause over-charge, and the battery temperature may rise up quickly.

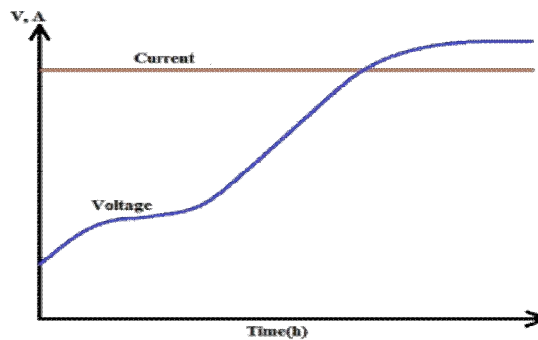


Fig. 2 Charging curve using CC mode

c). Constant Voltage - Constant Current charging mode:

The CV-CC charge mode combines both CV and CC charging method. At the initial charging stage, the constant current is used to charge the battery until the battery voltage reaches over-charged stage or pre-defined voltage. Then, the charging mode will switch to CC one to maintain the battery voltage, avoiding too high voltage. Fig. 3 indicates its charging curve. The advantage of this method is that the charging time can be reduced dramatically. Note that the typical value of maximum charging current is  $C/10$

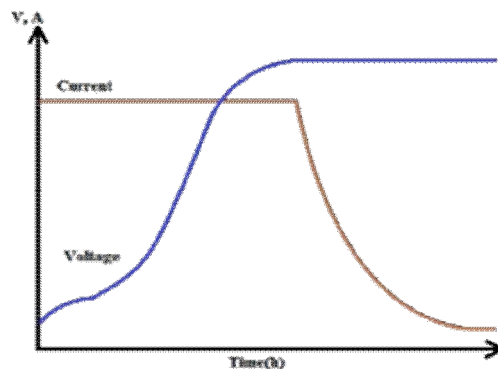


Fig. 3 Charging curve using CV-CC mode

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d).Pulse charge mode:

Fig. 4 depicts the profile of pulse charge cycles. Each charging cycle includes “charge” and “rest” stage. In the “charge” period, the battery is charged. In the “rest” period, the battery is at a rest status where the battery has more time to balance the battery chemical reaction. As a result, the battery voltage will become more stable, and its working life can be prolonged. Another advantage is that the charging time can be decreased using a large current which may be over-rated.

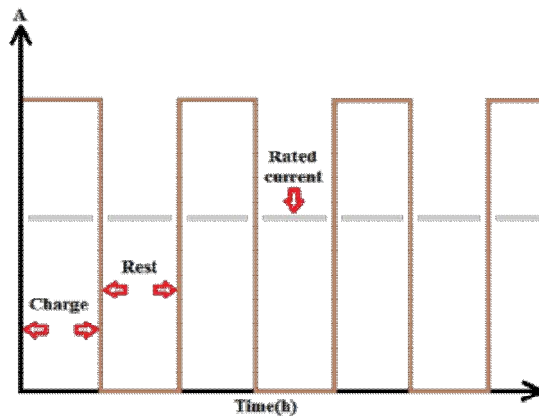


Fig.4 Depict of pulse charge

e). Positive and negative pulse charge:

The concept of applying a short discharge pulse during the charge cycle sometimes referred to as "reflex charging" or "burp charging" started with patents 3,597,673 "Rapid charging of batteries" W. Burkett & J. Bigbee in 1971 and 3,614,583 "Rapid charging of batteries" in 1971 by W. Burkett & R. Jackson. Some of the fast charging systems presently available incorporate negative pulse fast charging algorithms that claim to have great benefits to batteries including reduced recharge time, lower temperature rise, full recharge capabilities, as well as shorter equalization times. Also, lots of experimental results support that the negative pulse could eliminate the polarization effective. However, this method may reduce charge efficiency [17-19].

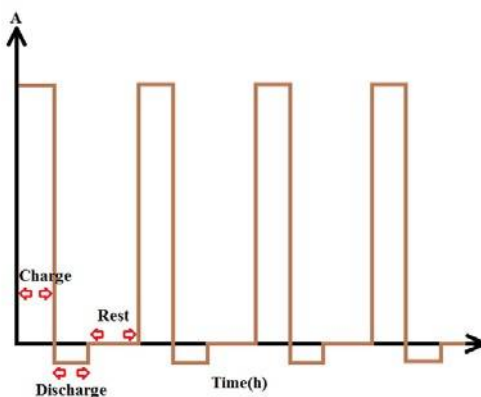


Fig. 5 Depict of positive and negative pulse charge

The best performance of the lead-acid cells can be achieved using a four state charge algorithm. In Fig. 1, the charge states from the first to fourth one are trickle charge, bulk charge, over charge, and float charge, respectively. This method integrates the constant current charge to recharge and equalize the lead-acid cells quickly and safely. With the constant voltage, it performs the controlled over-charge and retains the battery's full charge capacity in float mode applications. The carefully tailored charging procedure can maximize the capacity and life expectancy of the battery.

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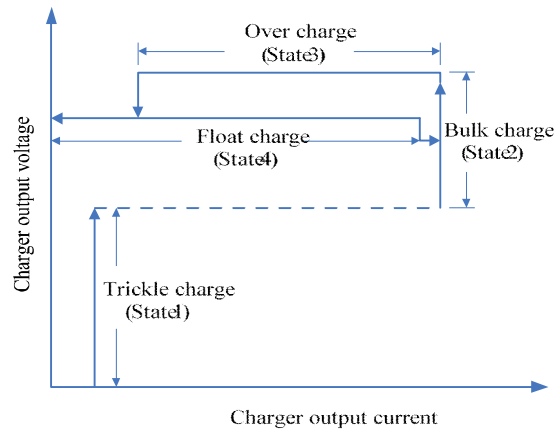


Fig. 6 Four state charge diagram

More details for the four-state charge from Fig. 6 is described as follows, respecting its ideal charge curve, shown in Fig. 5.

State 1 - A pre-charge current ( $I_T$ ) is applied to a completely discharged battery until a voltage,  $V_T$ , is reached. Normally,  $V_T$  is set low enough so that if a cell is shorted, no high rate charging will commence.

State 2 maximum State 2 allowable - The bulk constant charge current, state where  $I_{MAX}$ , the is applied to rapidly charge the battery into the overcharge condition. During this time, the majority of the battery capacity is quickly restored. The bulk charge mode is terminated when the battery voltage reaches the over-charge voltage level ( $V_{OC}$ ).

State 3 - When the voltage rises past  $V_{12}$ , an over-voltage state is entered where the battery voltage now applies a constant level,  $V_{oc}$ . The initial current value equals the bulk charge current, and as the battery approaches its full capacity, the charge current becomes will sufficiently taper off. low When ( $I_{OCT}$  the charge), the charging process is essentially finished and the charger switches over to float charge.

State 4 - During this state, the current will be whatever is necessary to maintain maximum back to State 2 and reapply capacity. If the battery should become loaded, when the voltage falls below  $V_{31}$ , the charger will switch  $I_{MAX}$ , initiating a new cycle.

Some critical points in the four state charge diagram are illustrated as follows.

A: When the input supply power turns  $I_T$  on, ratethe to battery charges at trickle current ( avoid the possible short circuit. It is in the state

B: The 1. battery voltage( $V_{AB}$ )reaches  $V_T$  will enable the driver and turning off the trickle bias output, and then the battery starts to charge at

C: When  $I_{MAX}$  ratethe, where it is in the state 2transition voltage  $V_{12}$  .is reached, and the charger indicates that it is now in the over-charge state, i.e., state 3.

D: When the battery  $V_{OC}$  voltage, the charge current approaches will the over-charge level

E: When the cbegin to taper.harge current tapers to  $I_{OCT}$ . The current sense amplifier output, in this case tied to the OC TERMINATE input, goes high. The charger changes to the float statebattery voltage at  $V_F$ . and holds the

F: Here a load ( $> I_{MAX}$ ) begins to discharge the battery.

G: The load discharges the battery such that  $V_{31}$ . The charger is the battery voltage falls below now in state 1, again

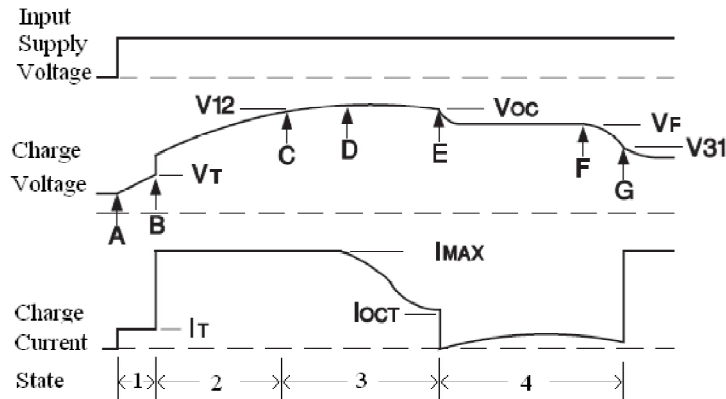


Fig. 7 Four state charge graph

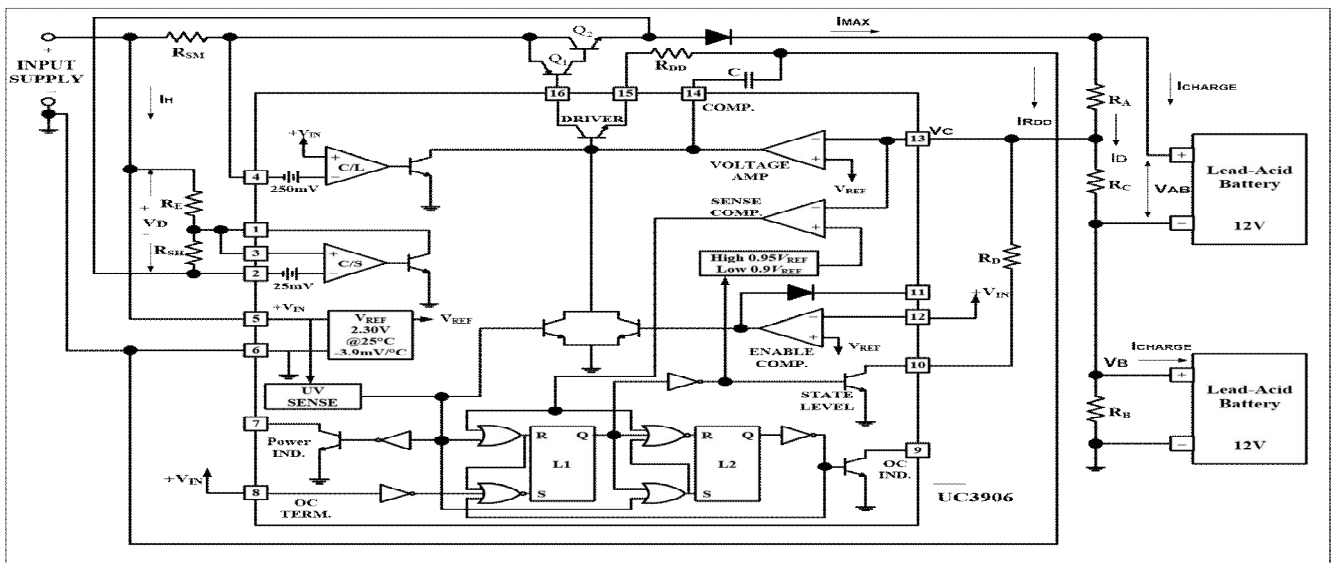


Fig. 8 Hardware of multi-state charge controller

### III. EXPERIMENTAL RESULTS

The effectiveness of the proposed algorithm has been tested and verified using both two and four series-connected 12V 150AH batteries. Initially, set INPUT SUPPLY voltage=30V, VOC=14V, VF=13.8V and I<sub>H</sub>=1A for two 12V-battery charge. Also, choose  $\beta_1 = 36$ ,  $\beta_2 = 210$ . According to the eqs. (1)-(10), all As can be seen, higher maximum charge current ( I<sub>MAX</sub> ) reduces the charge time significantly. In contrast, lower maximum charge current ( I<sub>MAX</sub> ) requires more time to achieve the full charge. Obviously, every figure has confirmed a reasonable outcome. For example, 7A charge current , needs more than 8 hours to achieve the full charge. On the other hand, 15A charge current shown in Fig. 13 takes only less than 3 hours to reach a full-charge level. Moreover, in every case the charging current is soon down to the holding current ( I<sub>H</sub> ) once the battery voltage reaches the overcharge ( VF=13.8V ).

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## IV. CONCLUSIONS

This paper has developed a well-optimized fast charger for a large size of lead-acid battery successfully. The proposed method can fast charge the battery using an appropriate large constant current without significant temperature rising. Once the battery reaches the over-charge state, the charger will soon enter a float-charge state where it remains a small holding current. The experimental results confirm that the proposed charger can complete the charging process within 3 hours for both 24V and 48V battery charge. Unlike the conventional complex control circuit, the proposed scheme is superior in term of simplicity, efficiency and low cost. Based on the design procedure, it can be easily extended to a variety of series batteries charge

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An acknowledgement section may be presented after the conclusion, if desired

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