Maintenance techniques for rechargeable battery using pulse charging

Cheung T. K.[1], Cheng K. W. E.[1], Chan H. L.[2], Ho Y. L.[1], Chung H. S.[2], Tai K. P.[2]

The Hong Kong polytechnic University[1]
Digipower Technology limited[2]
eekong@polyu.edu.hk, eeecheng@polyu.edu.hk,
nelsonchan@digiptech.com, eebonus@polyu.edu.hk,
carsonchung@digiptech.com, raytai@digiptech.com,

Abstract – The objective of this paper is to investigate a charging method control techniques for charging lead-acid battery. The characteristics of lead-acid battery are presented that include the charging method affecting the capacity of battery. The conventional charging method is pointed out the merit and drawback. And also the Variable Pulse Width Charging is also presented in this paper. This method is modified from the conventional method to enhance the life cycle and capacity.

Keywords: Charger, Lead-acid battery, battery maintenance, pulse charging, VPWC

INTRODUCTION

Government promotes Environmental protection. Electric Vehicle, EV, is proposal to replace motor vehicle and motorcycle to reduce the air pollution [1]. The one of major problem of population of EV is the charging time of battery.

Using general method to charge lead-acid battery, it can charge up the battery to near 100% capacity using rated current but the charging time would be too long. According to the market trend of battery charger, it should become more needs of fully charged and fastest time to finish the charging process. Using high current to inject to battery, it can minimize the charging time to meet the preset voltage. However, the capacity of battery is directly proportional to charging. The result is fast charge up that fast use up. And also the temperature problem is appearing in high current injection.

Considering the battery, battery needs enough electrolytes that its loss will result in reduction of electrolyte capacity. Relex ™ has been proposed [4]. The charging currents include positive, negative pulse and relax time. It is shown in Fig 2 that it provides a good performance and life cycle of battery. However, a discharge resistor or regeneration system is needed to release the energy. It will increase the cost of charger. This paper proposes another method to use in lead-acid battery it can provide fast charging; recover the capacity of battery; maintain capacity after each charging.

In this paper, the characteristics of lead-acid battery are tested. Different charging method is pointed out. The proposed method and its result are presented.

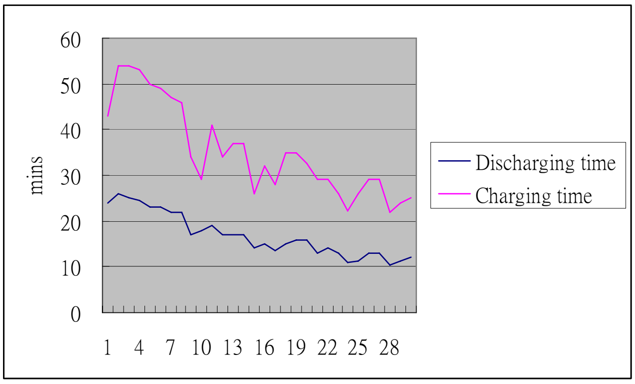

Fig 1 Charging time vs Discharging time

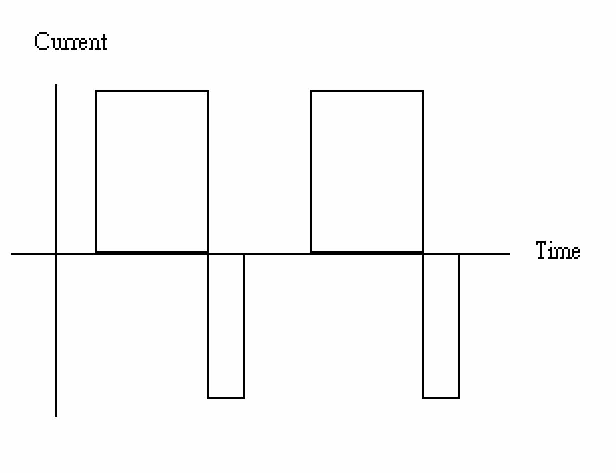

Fig 2 Current waveform of Relex ™

CHARGING METHODS

Lead-acid battery use Traditional Charging Method, they are Constant current, Constant Voltage, constant current constant voltage (CCCV) and pulse charging.

Constant current charging

Constant currents are used to charge the battery. This method is simple that using current monitoring, however monitoring the voltage of battery is to prevent the over-discharging by higher voltage. It will result in shortening the battery life.

Constant voltage charging
Constant voltage is used to charge the battery. This method is easy to implement but only the initial current required limiting to protect the charger. The drawback of this method is the charging time longer than Constant Current method.

Constant Current Constant Voltage charging (CCCV)
Combine the above methods, CCCV charging method is established. Constant Current is used at initial stage for providing starting charging current. Until the voltage charge up to cutoff or preset voltage, battery is switched to Constant Voltage mode to be a float charge.

Pulse Charging
Similar to Constant Current method but the pulsed current is used to inject to battery. It is given a relax time in each charging cycle. Using this method can neutralize the internal electrolyte of battery and enhance the life cycle of it. Also the large pulse current can decrease the charging time of battery.

Proposed Pulse Charging Method

Variable Pulse Width Charging (VPWC)
To increase the charging performance of battery, the current pulse will be adjusted to corresponding width for different modes. The current waveform is shown in Fig 3. The battery is charged by large pulse width in the first stage. Until the battery charge up to preset voltage, the battery defined as fully. The pulse width decreased to small value. The battery has more relaxed time. A control system sets up in the charger.

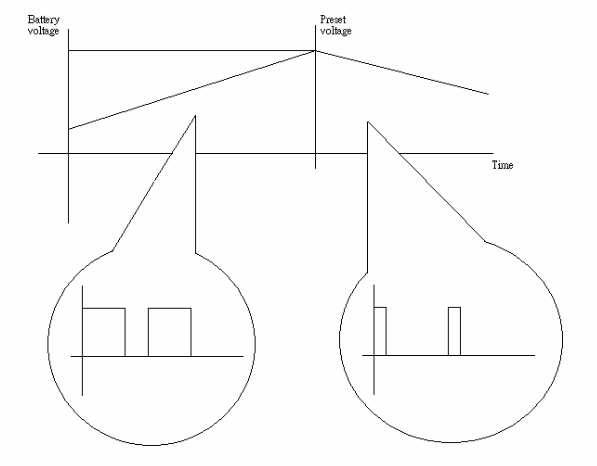

Fig 3 Current waveform of VPWC

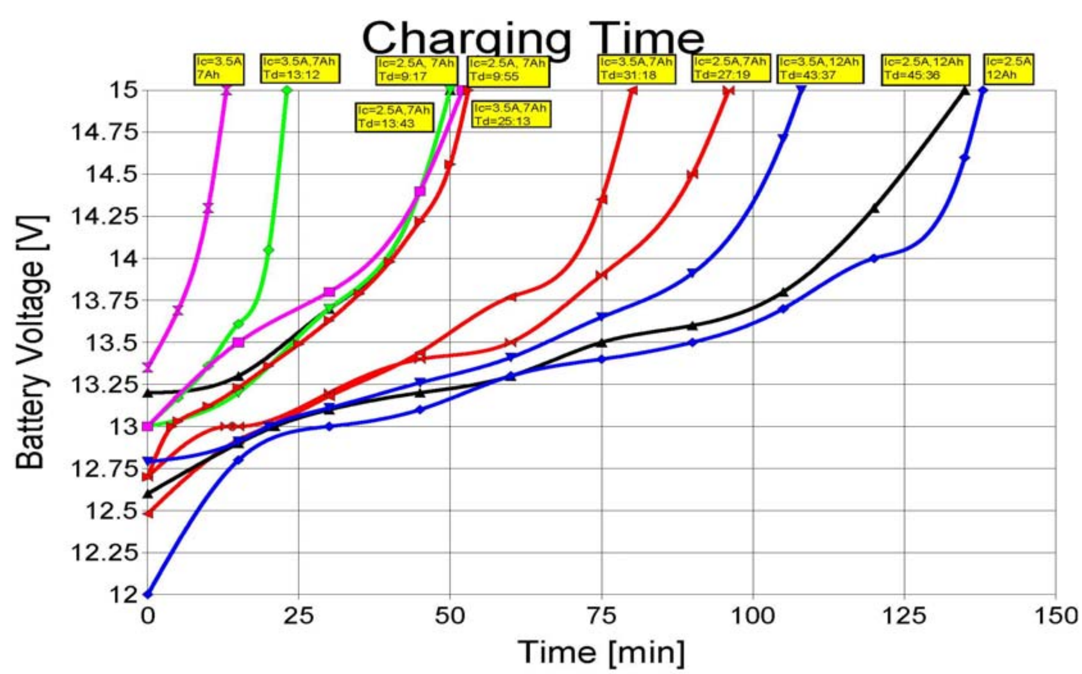

Fig4: Battery charging characteristics for the 7Ah and 12Ah

CONTROL LOOP

Two current control loops control the VPWS. Inner loop is a constant current loop. It controls the current to maintain at preset value. The outer loop controls the pulse width depend on the time, battery voltage and temperature. Time is limited for preventing over-charging time of battery. Battery voltage is used to switch the mode of charge. Temperature is mainly to protect the charger and battery.

EXPERIMENTS

Circuit Topology
Two types of converters is used to do this experiment:

a) DC/DC
Buck-boost converter
10-17V input
12-15.5V input
3.5A output

b) AC/DC
Flyback converter
220Vac input
12-15.5V input
2.5A output

Battery Testing
Two types of batteries are used in this testing, 7Ah and 12Ah and all are 12V. The result is shown in Fig 4. Continuous constant Currents are used to charge the battery. The result is shown that the high current injection to lead-acid battery is given a fast charging time but the discharging time will be decreased. After number of charging of an old battery, the capacity is decreased. This shows that the capacity is affected by high current injection.

Constant Charging vs. Proposed Pulse Charging in DC/DC

To show the difference between Constant Charging and Proposed Pulse Charging, the following Testing Conditions are used:

Charging:
For the Constant Current Charging:
The Charging Specification should be 3.5A / 16V, and the batteries are 12V / 7Ah. Charging Time set to one hour.

For the Proposed Pulse Charging:
The Charging Specification should be 4.375A / 16V with 80% duty, frequency are 1 Hz, and the batteries are 12V / 7Ah. Charging Time is set to one hour.

Discharging
Use 1C Discharge rate to discharge the batteries until 10.5V. The calculation the Discharge time for determining battery capacitance is shown below:

The result is shown below:

Method	Discharge Time(min)	Batteries Capacitance
Steady	21:56	36.6%
Pulse	25:29	42.5%

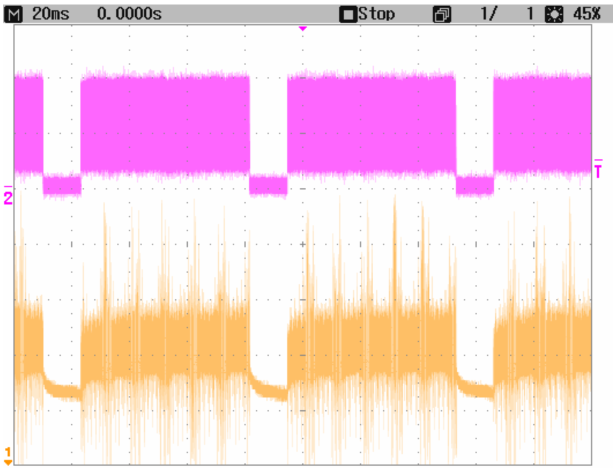

Fig 5: Voltage and Current waveform of proposed method

The voltage and current waveform is shown in Fig 5 . The current is shown in the graph that is charging in the first stage. Voltage waveform shows that the off time gives the battery relax time because the voltage drop in off time.

ELECTROMAGNETIC COMPLIABILITY

EMC is considered in this paper. Electromagnetic interference (EMI) is mainly come from switching devices of circuit. The outer loop controls the reference level of inner loop.
Inner loop control the principal PWM signal that it involves the high switching frequency. The EMC report is shown below in Fig 6 and 7.

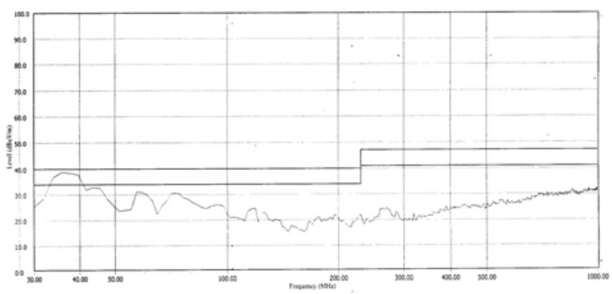

Fig 6: Radiative spectrum

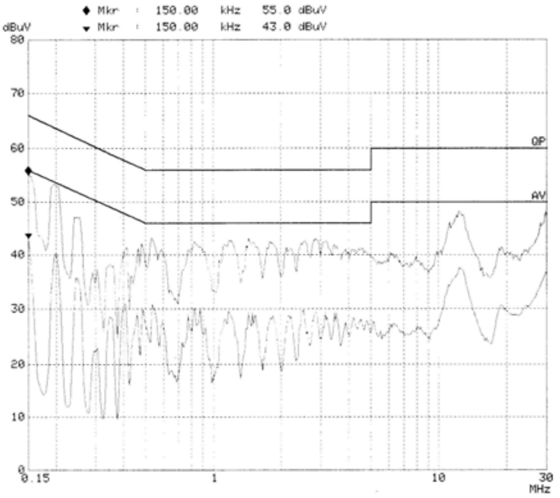

Fig 7: Conductive spectrum

Result of EMC reports show the charger passes the EMC standard.

CONCLUSION

This paper presents a charging method VPWC. It uses different widths of current pulse to charge up the lead-acid battery. It gives different relax time for different states of battery. Battery's capacity will be recovered by using VPWC but it does not require any additional resistor or regeneration system to release the negative currents' energy, like reflex™. In the future development of this type of charger, polymer bond magnetic is considered to apply to it. It can reduce the weight of charger and have flexibility of size advantage.

ACKNOWLEDGMENT

This work is supported by Guangdong-Hong Kong Technology Cooperation Funding Scheme, Innovation and Technology Fund, under project GHP/066/05.

REFERENCE

[1] Chih-Chiang Hua; Meng-Yu Lin, "A study of charging control of lead-acid battery for electric vehicles", Industrial Electronics, 2000. ISIE 2000. Proceedings of the 2000 IEEE International Symposium Volume 1, 4-8 Dec. 2000, pp.135 - 140.

[2] Gonzalez, M.; Perez, M.A.; Diaz, J.; Campo, J.C.; Horta, S., "New intelligent Ni-Cd and Ni-MH battery fast-charger", Industrial Electronics, 1997. ISIE '97., Proceedings of the IEEE International Symposium, Volume 2, 7-11 July 1997, pp. 501 – 506.

[3] Barsali, S.; Ceraolo, M., "Dynamical models of lead-acid batteries: implementation issues", Energy Conversion, IEEE Transactions, Volume 17, Issue 1, March 2002, pp. 16 - 23

[4] Chu, Y.S.; Chen, R.Y.; Liang, T.J.; Changchien, S.K.; Chen, J.F., "Positive/negative pulse battery charger with energy feedback and power factor correction", Applied Power Electronics Conference and Exposition, 2005. APEC 2005. Twentieth Annual IEEE, Volume 2, 6-10 March 2005, pp.986 – 990.

[5] Lohner, A.; Karden, E.; de Doncker, R.W., "Charge equalizing and lifetime increasing with a new charging method for VRLA batteries", Telecommunications Energy Conference, INTELEC 97., 19th International, 19-23 Oct. 1997, pp. 407 - 411

[6] Hu, A.P.; Chen, Z.J.; Hussmann, S.; Govic, G.A.; Boys, J.T., "A dynamically on-off controlled resonant converter designed for coalmining battery charging applications", Power System Technology, Proceedings. PowerCon 2002. International Conference, Volume 2, 13-17 Oct. 2002, pp.1039 - 1044 vol.2