Evaluation of Battery charging techniques

This study thoroughly evaluates traditional charging techniques and fast charging techniques for rechargeable batteries. The evaluation is completed so as to supply higher charging techniques to charge the batteries faster, more proficiently while as yet giving careful consideration to maximize the utilized batteries capability and also the utilized batteries life expectancy.

1. Traditional Charging Techniques

1.1 Continuous Current Trickle Technique

This technique depends on continual currents. Little charging currents will cause the charge time to be long. The chargers are relatively simple and inexpensive to design. They're not considered as technologically advanced chargers and they rely completely on the user to start and terminate the charge. However, the drawback is that it may cause overcharge, and also the battery temperature might rise quickly, influencing the battery life [1]-[3].

1.2 Continuous Current Fast Technique

This technique where a battery gets a large current until the point when it is completely charged. This idea will scale back the battery charging time from 10 hours under consistent current trickle charge to 3 hours in quick steady current charge. The

quick steady current charging method does not consider the inner electrochemical process of the battery being charged leading to vital negative long-run effects [17, 18].

Dendrites growth, giant metallic crystal formation and accumulated internal resistance caused by the massive constant charging current result in reduced battery capability and shortened life cycle.

1.3 Continuous Voltage

Continuous voltage (often called constant potential). Is a method that almost maintains the same voltage input of the battery; throughout the charging process. This voltage is determined by the manufacturer's specifications. Upon the battery's voltage reaching the default, the charging current declines. However, too much current can cause overcharge that results in grid corrosion which in turn influences the behavior and lifespan of the battery [1]-[3].

1.4 Continuous Current & Voltage

This technique combines both constant voltage and current (also known as the "two-step" method). The current relies upon the power limitations which means the charger limits the current volume to a pre-set level until the battery reaches a pre-set

voltage level. Therefore, and supported the preceding current is reduced gradually till the battery is completely charged [3] – [5].

1.5 Pulse Method

Through this method a consistently pulsed current is applied to the battery, involving a pulse charge followed by a short deep discharge and consequently a holding up period. Short rest periods between pulses, shall work to enhance the chemical actions within the battery to be stabled via equalizing the reaction throughout the charge of the electrode before charge re-combination [1, 8, 9]. The preceding three steps shall be iterated until the point when the battery is totally charged. However, a noteworthy inconvenience of the pulse technique is poor effectiveness [2, 7].

The pulse charging idea derived from considering the way that an extended consistent current charge prompts an ion concentration gradient to build abreast of the ion generating electrode because of the mass transport restrictions inside the battery. This results in dendrites outgrowth, metallic crystal formation and arises within the internal resistance of the battery which thus results in heat generation, poor battery charge proficiency, poorer battery capability and shorter battery life expectancy [10].

2. Fast Charging Techniques

2.1 Interrupted Charge Control

In Ref. [11], developed a new thought of intermittent charging wherever the battery is charged irregularly on an intermittent premise to its full-charge capability, and after that, the battery is kept in an open-circuit condition along these lines diminishing the nonstop and destructive electrochemical responses. During this approach the charging is repeated intermittently, reducing harmful overcharging and expanding the battery life by maintaining a strategic distance from the continual float conditions.

2.2 Method and Apparatus for Rapidly Charging and Reconditioning a Battery

In Ref. [12], the authors licensed a charging technique and mechanical assembly intended to rapidly and effectively charge batteries while at the same time reconditioning them. Unsatisfied with earlier workmanship battery chargers related with long charging circumstances, wasteful charging, and steady decrease in charge acceptance and in life cycles, Pittman et al. engineered a fast and effective charger supported pulse charging technique.

Observing that steady current chargers will simply harm a battery by overestimating the consistent charge current which may eventually fully destroy a useful battery , and that pulse chargers that attempt to convey bursts of energy to rechargeable batteries through pulses typically operate at a high charging voltage that gets the task done faster at the expense of step by step devastating the battery through warmth

generation and electrolyte evaporation, Pittman et al. chosen to run with a pulse charging rule containing a periodic combination of charging pulses, discharging pulses and recovery periods so as to significantly enhance some constraining factors of charge acceptance of batteries.

The charging sequence demands to apply a discharge pulse promptly before the charging pulse so as to limit the interior impedance of the rechargeable battery and thus with efficiency utilize a lower recharge voltage resulting in lower energy wasted in heat and higher charge acceptance.

2.3 Rapid Charging of a Battery by Applying Alternating Pulsed Large Current without a High Temperature

In Ref. [13], a genus proprietary a straightforward charging methodology of a pulse charging technique to attain a quick battery charge whereas keeping away from battery overheating and potential overcharge. Note that Chen's charging technique, however, is to be applied on nickel-cadmium and nickel-metal-hydride batteries only.

No mechanical assembly has been created alongside Chen's patent to exhibit how to do the charging idea appropriately. Besides, whereas the disclosed proprietary charging technique is so straightforward and sensible it doesn’t do a lot of limits a few negative impacts, for example, dendrites growth, extensive metallic crystal formation, and enlarged internal resistance and reduced battery lifespan. Additionally, Chen’s charging technique isn't universal and doesn't account for all battery types.

2.4 Battery State of Charge Detector with Rapid Charging Capability and Method

In Ref. [14], the author's driven by the belief that there is a requirement for an “efficient and rapid " battery charger that ought to " facilitate optimum performance from a rechargeable battery " licensed a progressed electronic plan that polls a rechargeable battery at normal intervals to determine its state of charge. Many factors account for the figured estimation of the state of charge, specifically the battery’s temperature, pressure, ohmic resistance, and corresponding phase angle. Once the state of charge is figured then the battery gets recharged in line with a planned pulse charging design, consisting of positive pulses, negative pulses, or a mixture of each, recorded on an operation table specifically for the contemporary determined state of charge esteem.

Additionally, so as to determine the battery’s inner impedance and electrochemical overvoltage, Ding et al. allude to utilizing guess procedures that won't be exact. Electrochemical Impedance Spectroscopy (EIS) generally, a technique went for estimating the interior impedance of a device by sending an AC current and measure its response at various frequencies depends on three distinct factors, specifically temperature, state of charge and DC-current.

2.5 Rapid Battery Charging Method and Apparatus

In Ref. [15], fast battery chargers that can rapidly recharge lead-acid batteries without lessening their service life patented a development fit for reviving lead-acid batteries in less than two hours.

The disclosed charging technique is a unique instance of pulse charging techniques. Aperiodic charge/rest/discharge/rest charging waveform is applied for 2 hours till the battery (hopefully) achieves its full charge. Vladimir Petrovic plainly expresses that his development depends on the described specific charging waveform since he found that this charging cycle has “unexpectedly useful impacts in that, compared to standard charging cycles, it lessens the time taken to bring a battery to full charge and will increase the overall charge which will be delivered to the battery.”

2.6 High Current Pulse charging

In Ref. [16], utilized a high current pulse of a specific pulse width special wavelength for prolonging the lifetime of lead-acid batteries. The device that executed was named the “High current pulse activator”. It absolutely was through an experiment verified that this device was effective to eliminate sulfation, refreshes the negative electrode and prolongs battery life.

2.7 Internal Voltage Control

In Ref. [17], the authors studied the new technique of charging and discharging have created to enhance the performance of charging and discharging of lead-acid batteries. At the point when the effective inner resistance of the battery is increased because the deterioration, the external voltage is just too high to prevent charging despite the fact that the battery has not stored a sufficient quantity of energy, these ways affirmed that the interior voltage control functions well for the way toward charging-discharging. The lifetime of batteries is considerably extended and also the

capacity of batteries will sufficiently utilize once the interior voltage control is employed.

2.8 Battery Recovering by applying Pulse Current

In Ref. [18], utilized a pulse current to the lead-acid battery is known as the strategy of recuperating the performances of the lead-acid battery, which are corrupted by sulfation. The desulfation system includes signal produced design to get a pulse wave drive signal, provides a back electromotive force and invert current to the lead acid battery in synchronicity with a falling edge of the pulse wave drive wave, hence shorting the timeframe needed for removal sulfation.

Reference

[1] Spanos, C., Berlinger, S. A., Jayan, A., & West, A. C. 2016. Inverse charging techniques for sulfation reversal in flooded lead-acid batteries. *Journal of The Electrochemical Society*, *163*(8), A1612-A1618.

[2] Hua, C. C., & Lin, M. Y. 2000. A study of charging control of lead-acid battery for electric vehicles. In *Industrial Electronics, 2000. ISIE 2000. Proceedings of the 2000 IEEE International Symposium on* (Vol. 1, pp. 135-140). IEEE.

[3] Horkos, P. G., Yammine, E., & Karami, N. 2015, April. Review on different charging techniques of lead-acid batteries. In *Technological Advances in Electrical, Electronics and Computer Engineering (TAEECE), 2015 Third International Conference on*(pp. 27-32). IEEE.

[4] Linden, D., & Reddy, T. B. 2002. *Handbook of batteries*, 2002. *1e42*, *4*.

[5] Baroody, R. 2009. Evaluation of rapid electric battery charging techniques.

[6] Abdollahi, A., Han, X., Avvari, G. V., Raghunathan, N., Balasingam, B., Pattipati, K. R., & Bar-Shalom, Y. 2016. Optimal battery charging, Part I: Minimizing time-to-charge, energy loss, and temperature rise for OCV-resistance battery model. *Journal of Power Sources*, *303*, 388-398.

[7] Cheng, P. H., & Chen, C. L. 2002, November. A high-efficiency fast charger for lead-acid batteries. In *IECON 02 [Industrial Electronics Society, IEEE 2002 28th Annual Conference of the]*(Vol. 2, pp. 1410-1415). IEEE.

[8] Zhang, J., Yu, J., Cha, C., & Yang, H. 2004. The effects of pulse charging on inner pressure and cycling characteristics of sealed Ni/MH batteries. *Journal of power sources*, *136*(1), 180-185.

[9] Li, J., Murphy, E., Winnick, J., & Kohl, P. A. 2001. The effects of pulse charging on cycling characteristics of commercial lithium-ion batteries. *Journal of Power Sources*, *102*(1-2), 302-309.

[10] Baroody, Ronald. 2009, Evaluation of rapid electric battery charging techniques, M.S. thesis, Nevada Uni, Las Vegas.

[11] Reid, D. P., & Glasa, I. 1984, November. A new concept: intermittent charging of lead acid batteries in telecommunication systems. In *Telecommunications Energy Conference, 1984. INTELEC'84. International* (pp. 67-71). IEEE.

[12] Pittman, R. W., & Stefansson, H. 1999. *U.S. Patent No. 5,998,968*. Washington, DC: U.S. Patent and Trademark Office.

[13] Chen, J. C. M. 2000. *U.S. Patent No. 6,060,865*. Washington, DC: U.S. Patent and Trademark Office.

[14] Ding, Y., Michelson, R., & Stancil, C. 2000. *U.S. Patent No. 6,094,033*. Washington, DC: U.S. Patent and Trademark Office.

[15] Baroody, R. 2009. Evaluation of rapid electric battery charging techniques.

[16] Ikeda, H., Minami, S., Hou, S. J., Onishi, Y., & Kozawa, A. 2005. Nobel high current pulse charging method for prolongation of lead-acid batteries. *Journal of Asian Electric Vehicles*, *3*(1), 681-687.

[17] Hou, S. J., Onishi, Y., Minami, S., Ikeda, H., Sugawara, M., & Kozawa, A. 2005. Charging and discharging method of lead acid batteries based on internal voltage control. *Journal of Asian Electric Vehicles*, *3*(1), 733-737.

[18] Kondo, T. 2013. *U.S. Patent No. 8,519,672*. Washington, DC: U.S. Patent and Trademark Office.