Proceedings of IOE Graduate Conference, 2017
Volume: 5 ISSN: 2350-8914 (Online), 2350-8906 (Print)

Effect of Pulse Charging in Lead acid Batteries Used in Electric Vehicles of Nepal

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Abstract
The major factor in reducing the life of the lead acid battery is sulfation. Sulfation forms a layer of Lead Sulphate crystal in the electrodes making it less conductive or even blocking the electrical current to pass through it. Soft sulfation is removed by the method of gassing which however does not work for hard sulfation. This research is focused on finding the effect of pulse charging in the deep cycle batteries used in electric vehicles in Nepal. Effect of charging with frequencies from 1 KHz to 2.5 MHz is studied in this research. The tests in lab showed positive effect in desulfation and also found out the frequency greater than 5 KHz are suitable for desulfation.

Keywords
Lead Acid battery – Sulfation – Desulfation – Pulse Charging

1. Introduction

Most of the world's lead–acid batteries are automobile starting, lighting and ignition (SLI) batteries, with an estimated 320 million units shipped in 1999. In 1992 about 3 million tons of lead were used in the manufacture of batteries. Wet cell stand by (stationary) batteries designed for deep discharge are commonly used in large backup power supplies for telephone and computer centers, grid energy storage, and off grid household electric power systems [1].

According to a 2003 report entitled "Getting the Lead Out", by Environmental Defense and the Ecology Center of Ann Arbor, Mich., the batteries of vehicles on the road contained an estimated 2,600,000 metric tons (2,600,000 long tons; 2,900,000 short tons) of lead[2]. Some lead compounds are extremely toxic. Long-term exposure to even tiny amounts of these compounds can cause brain and kidney damage, hearing impairment, and learning problems in children [3].

The auto industry uses over 1,000,000 metric tons (980,000 long tons; 1,100,000 short tons) every year, with 90 percent going to conventional lead–acid vehicle batteries. While lead recycling is a well-established industry, more than 40,000 metric tons (39,000 long tons; 44,000 short tons) ends up in landfills every year. According to the federal Toxic Release Inventory, another 70,000 metric tons (69,000 long tons; 77,000 short tons) are released in the lead lead–acid battery became a commercial item, to reduce lead sulfate build up on plates and improve battery condition when added to the electrolyte of a vented lead–acid battery. Such treatments are rarely, if ever two compounds used for such purposes are Epsom salts and EDTA [4]. Epsom salts reduces the internal resistance in a weak or damaged battery and may allow a small amount of extended life. EDT A can be used to dissolve the sulfate deposits of heavily discharged plates [5]. However, the dissolved material is then no longer available to participate in the normal charge/discharge cycle, so a battery temporarily revived with EDT A will have a reduced life expectancy. Residual EDT A in the lead–acid cell forms organic acids which will accelerate corrosion of the lead plates and internal connectors.

Discharge test is the method for finding the true capacity of the battery. The table 2.1 shows the capacity of the battery when discharged in different loading condition. If the battery is discharged higher than the rated capacity the capacity is reduced.

2. Methodology

The method of the research is experimental in which different patterns and relations found between the parameters of the battery are analyzed.

2.1 Experimental Setup

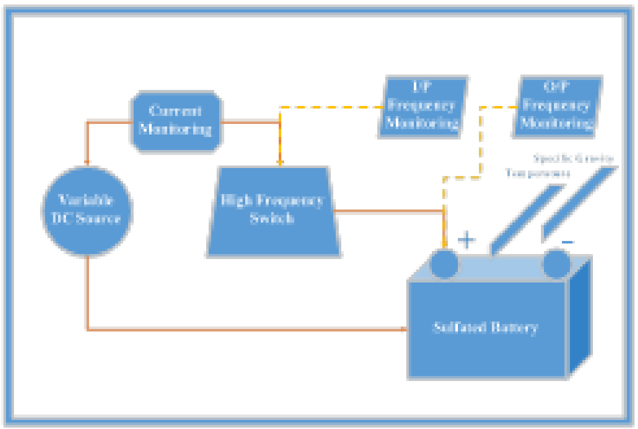

Figure 1: Experimental setup

The basic tests performed included the pulse charging of flooded and VRLA type lead acid batteries in various frequencies with the maximum of 2.5 MHz. The change in specific gravity and internal resistance with time was observed. In the field test traction batteries used in electric vehicles of Terai region of Nepal were subjected to test. The desulfated batteries were further tested for capacity determination by discharge test. The discharge test parameters for the revived batteries are compared with the brand new battery of same type and capacity with full charge on both.

2.2 Internal resistance

Internal resistance of the battery is measured using a setup for high discharge current. During the high discharge the voltage across the battery terminal and the current flowing through the battery are measured. The internal resistance of the battery is dependent to the rated discharge capacity. In traction batteries the internal resistance is preferred to be around 0.2 ohms [6].

2.3 Specific Gravity

The electrolyte in the lead acid battery is dilute Sulfuric acid. H2SO4 is heavy than water and pure H2SO4 has specific gravity of 1.7 but the one used in the battery has the specific gravity of 1.3. Hydrometer is the instrument used in measuring the specific gravity of the electrolyte. The higher value of the specific gravity signifies the higher level of charge in the battery. The specific gravity is monitored during the charging to confirm rise in charge level.

2.4 Voltage

Battery voltage is also an indicator in of the level of charge in the battery but the specific gravity is also needed to confirm it. When battery gets old the voltage rises fast but the specific gravity is not increased which signifies the deterioration of the battery capacity. Battery voltage reaches 13.7V in full charge but this value might go up to 14 V. Voltmeter is used to measure the voltage the battery.

2.5 Discharge test

Discharge test is the method of actually measuring the capacity of the battery. The battery rating are not true if the standard is not maintained. Measuring the battery discharge current and the discharging voltage the battery capacity can be measured. If same process is carried out in different batteries of same model their capacity can be compared to one another. The relation of discharge current and capacity is shown in figure 2-9 which can be used to calculate the capacity.

3. Results and Discussion

The results from the lab tests were showed the optimal frequency for pulse charging in field. The charger developed for the desulfation charging costs higher if it needs to be designed for high frequency. On the other hand lower frequency may not be feasible for proper desulfation. In the first phase the lab tests were carried out with low power equipment and basic setup for highest frequency of 2.5 MHz.The upper frequency was selected to include the resonance frequency of the lead sulfate crystal of 2.3 MHz [6].

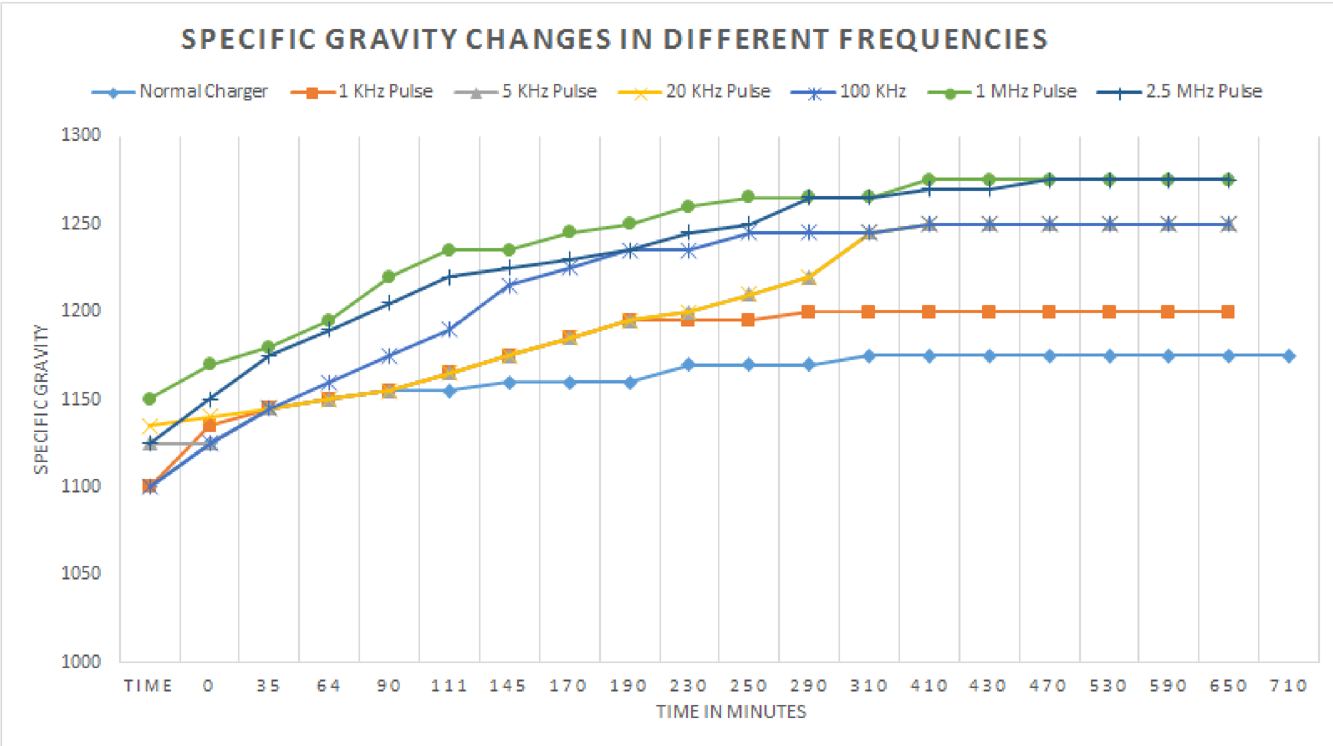

Figure 2: Lab result of battery charging at different frequencies

3.1 Lab Test Results

In the experiment different batteries were tested using normal charger and pulsed charger. The frequency of the pulsed charger was set to 1 KHz, 5 KHz, 20 KHz, 100 KHz, 1 MHz, and 2.5 MHz in the tests. The charge level seems to reach above the level in the normal charger. Different effects can be seen in different charging frequencies. The comparison of the pulsed charging and normal charging is shown on the figures. The changes in the internal resistance is also shown for the different batteries. As seen in figure 2 the normal charger could charge only to the level of 1165 were as the highest was obtained at 2.5 MHz with the value 1275. The charge level reached at 5 KHz is 1250 which is a good level and not much less than in 2.5 MHz. Developing a high current charger at lower frequency is easier and economic too. Tests to carried in the field used the frequency of 5 KHz for the same reason.

Internal resistance also decreased in pulsed charging but the change was more in the frequencies higher than 5 KHz, shown in figure 3. No significant effect is seen in 1 KHz. Data from the plot of internal resistance also suggests 5 KHz as optimum or usable.

3.2 Field Test Results

Fourteen batteries were put to test at 5 KHz in the field for 72 hours. Only fourteen batteries showed positive changes of desulfation. Two batteries heated and the charge level did not rise and were discarded for further tests. The batteries after reaching full charge were subjected to discharge test. As shown in table 1 the new batteries lasted for 5 minutes before reaching 9.6 Volts under 150 Ampere discharge test. Taking the performance of new batteries a the benchmark (100 percent), revival level of the other batteries are calculated. The highest one noted 93 percent and the lowest one 70 percent.

Two batteries failing to revive may be due to the internal damage of the lead plates. Batteries with physical damage on the plates due to overcharging and over discharging cannot be revived from the process of desulfation. Those batteries need to be recycled for reuse. Batteries without visible physical damage and some electrolyte level remaining are chosen in the first place for desulfation. This process does not guarantee revival of batteries in any condition and the success rate is found to be 86 percent from the field results.

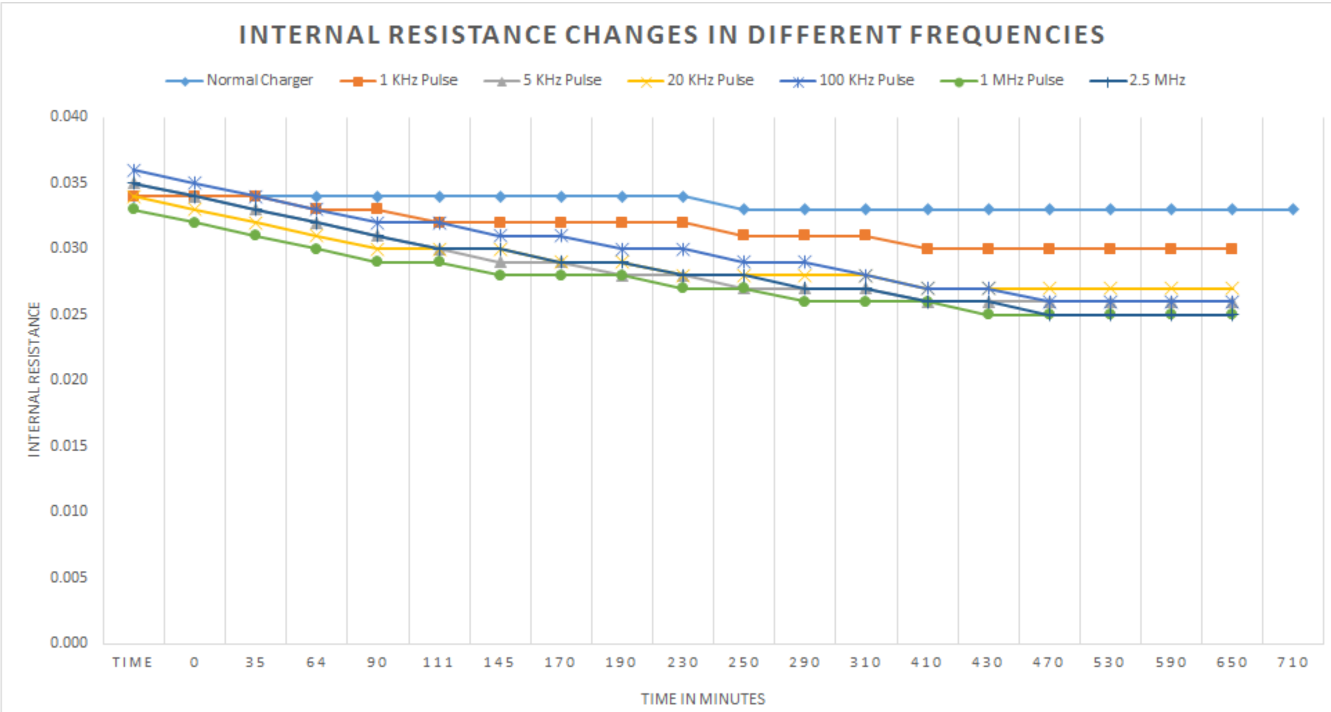

Figure 3: Internal resistance of battery charging at different frequencies

Table 1: Percentage of battery capacity compared to new battery

Battery Label	Time (min)	Percentage
B2	5	100
B4	4.83	96
B7	4.91	98
B8	4.86	97.5
B6	4.66	93
B5	4.5	90
BX8	4.32	86
BX7	4.38	88
B9	3.91	78
BX5	4.25	85
BX6	4.2	84
B10	3.83	77
BX4	3.66	73
BX3	3.58	72
BX2	3.5	70
BX1	3.66	73

4. Conclusion and Recommendation

The research on the pulsed desulfation showed positive inclination of the desulfation process when applied pulse charger. The pulse frequency was tested with the highest frequency of 2.5MHz. In the field test the results shows that some of the discarded lead acid batteries were revived up to 90 percent of the original condition. This process could help the vehicle owners if the process proves economical too. This research studied the effect of pulsed charging on lead acid battery.

The desulfation process was positive but there are further studies that can be useful. Some of them are listed below:

- The effect of frequencies higher than 2.5 MHz
- The effectiveness of higher or lower frequencies
- The economic viability of the process in commercialization
- The effect of reviving the battery used along with the chemical process

Acknowledgments

The authors are grateful to Mr. Suraj Karki, Mr.Takeshi Kawabe and Mr. Hiroshi Tominaga for their support in the the feild test. The authors are indebted to Japan

Battery Regeneration Company for their guidance and support with equipment. We extend our thankfulness to Nepal Innovation Center for arranging the logistics for the research.

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