WORKING WITH AND UNDERSTANDING BATTERY RECHARGE CURRENTS AND CURRENT LIMITS AFTER A BATTERY DISCHARGE EVENT OR TEST

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INTRODUCTION

This paper is written for battery service providers and end users who test and maintain their own batteries. I wrote this paper as a follow-on to the paper presented by Rick Tressler at last year's Battcon – Capacity and Discharge Testing. There are some very important battery and power plant considerations that need to be looked at and understood when recharging your batteries after a discharge event or test. Battery strings represent a large capital investment for a business and they are counting on them to provide them with emergency power when needed. Properly maintaining them is essential for optimum performance and life. The examples I use are primarily VRLA batteries installed in a telecom environment but the same considerations need to be looked at in UPS and flooded battery installations. This paper will cover the effects of improperly recharging batteries after a discharge test or event and the other factors you must take into account when recharging your batteries. Always consult with the battery manufacturer if you are unsure of the battery recharge rates.

THE CONSEQUENCES OF UNDERCHARGING OR OVERCHARGING YOUR BATTERIES

Undercharging a battery after a deep discharge can lead to a permanent loss in battery capacity from the hardening of the residual lead sulfate ($PbSO_4$) left on the positive and negative plates during the chemical reactions that took place during the discharge.[1]

Overcharging a battery can also lead to a permanent loss in battery capacity by increasing grid corrosion and consuming the water in the electrolyte leading to a dry out condition from excessive gassing.[2] The water loss is unique to the VRLA type of batteries because of their sealed vents. With Vented Lead Acid batteries or “wet” cells, water can be added over time. The VLA type of batteries are not affected with the dry out condition but the excessive gassing could lead to a hazardous condition with a build up of hydrogen gas in a poorly ventilated battery room. Overcharging a battery string will also generate high cell temperatures that can also impact the life of the battery. This overheating can lead to a thermal runaway condition.

TIME TO RECHARGE YOUR BATTERIES

Properly recharging your battery after a discharge test or extended power outage is critical for maximizing the life of your battery. This must be done as soon as possible after the test is complete to prevent potential irreversible damage to the cell by leaving it in a discharged state. This can lead to sulfation and hydration, both of which will damage the battery and affect the capacity and the life of the battery. Sulfated batteries are partially charged and have not completed the electrochemical reaction of recharge. Keeping the battery in this condition over an extended period can lead to irreversible damage to the cells. Hydration is when the specific gravity of the electrolyte has been reduced so low that the lead components of the cell dissolve into the electrolyte.[3] There are many details to examine when recharging your batteries. Overlooking one or all could do serious harm to the battery, affect your system integrity, and void your battery warranty[4].

[1] C&D Technologies Technical Manual 41-2128 Nov 1999 pg6
[2] C&D Technologies Technical Manual 41-2128 Nov 1999 pg3
[3] C&D MS Endur operation manual, RS-1991 pg 17
[4] East Penn Document form 0139 rev 3/04 pg2

You need to consider several factors when applying recharge current to a battery string.

- Battery Room Environment – is it hot?

If the battery room is already at or above 77° F, then you do not want to exceed the manufacturer's recharge current. If the battery temperature is above 90º, then you will need to lower the recharge current 5 to 10% to prevent overheating of the battery during the recharge process.[5] The recharge process will generate heat, and you will want to monitor the battery temperature during recharge and make sure it does not go into a thermal runaway condition. During recharge, you want to limit the temperature rise to less than 18ºF or 10ºC. If the battery temperature is rising above these temperatures, you need to reduce the recharge current. If the battery room is cool (less than 70° F), then you can recharge the battery with a little more recharge current.

- What type of battery am I recharging?

The battery recharge rates vary between VRLA and Flooded cells. Flooded cells are recharged at a lower rate due to the gassing of the cells. If you recharge a string of flooded batteries too fast, you could create a hazardous condition, with a build up of hydrogen gas.

- Who is the manufacturer?

Each battery manufacturer has different recharge guidelines. Some publish this data and some do not. Refer to the manufacturers I&O manual or consult with their technical support group if unsure. Here are some examples from different manufacturers.

Manufacturer	Battery Type / Model	Maximum Recharge Recommendation
Douglas	VRLA – Safeguard DSV, DSV-1240	Do not exceed the 8-hour (discharge) amp rating.[6] For this model it would be 155 amps.[7]
C&D	VRLA – MS Endure AT-15	Limit recharge current to 25 amps per 100-amp hour rating at the 8-hour rate.[8] For this model it would be 200 amps.[9]
GNB/Exide	VRLA- Absolyte IIP 100A31	Limit recharge current to 25-30 amps per 100-amp hour rating at the 8-hour rate. For this model it would be 400-480 amps.[10]

- What is the Battery disconnect rating?

If the battery string has a battery disconnect installed and you are recharging the battery string with the plant rectifiers, you must take the disconnect rating into account. This should also be checked on start up and during PM visits to ensure it is sized properly. As your loads grow, you need to keep an eye on the disconnect rating to make certain you do not accidentally exceed its rating.

Field Incident 1

Prior to coming to Liebert, I was hired by a small telecom provider in Oregon to provide consulting services and investigate why they lost all loads almost immediately during a power outage. The customer was in the process of replacing both battery strings. The single system had a 930-amp load and was backed up by two 2100 amp hour battery strings. The customer would have approx 4 hours of run time if both strings were at 100% capacity. The contractors had already removed and replaced one string and were in the process of replacing the second string. The second string was offline completing its initial charge, leaving only one string online. Both batteries were connected to the power plant with individual 600-amp battery disconnects. With both strings online, each would provide half the load, or around 450 amps each, but, with one string off line, the one remaining battery was going to try and supply the entire 930 amp load through a 600 amp disconnect. Load dump!

[5] C&D Powercomm Communicator April/May 1997
[6] Douglas Safeguard DSV I&O manual M0545 10-03, pg13
[7] Douglas Safeguard Discharge data manual M-0540 11-03, pg2
[8] C&D MS Endure operation manual, RS-1991 pg 11
[9] C&D MS Endure operation manual, RS-1991 pg 23
[10] This data is not published. This is the recommendation from their engineering group.

- What amperage are the battery connectors rated for?

Some manufacturers rate their battery connector straps for maximum current. For example, an East-Penn Deka-Unigy II AVR85-33 battery with an S-1 connector configuration is rated for 375 amps or less.[11] This factor also needs to be taken into consideration when engineering the site prior to installation and checked prior to starting a discharge test. Not doing so can lead to incorrect test results when performing a capacity test.

GNB's standard, low rate connector package is fine for discharge current rates above the 3-hour rate. If you are sizing your battery for a higher discharge rate, please consult with the battery manufacturer's engineers for the proper connector package needed to ensure your run time.

Field Incident 2

I was working on a crew installing a 240 cell VRLA battery (comprised of individual 2 volt cells) for backup power to a large 3-phase UPS. During the acceptance test, we were not meeting the 8 minute run time requirement. We were hitting the overall battery string cutoff voltage of 420 VDC (1.75 x 240) at 7 ½ minutes, but the individual cell voltages were above the 1.75 end voltage. After consulting with the battery manufacturer, it was decided that there were not enough battery connector laminations installed to meet the high rate discharge. The addition of extra intercell connector laminations reduced the overall battery string resistance, thus improving the battery performance. After stripping down the battery and adding additional laminations, the battery passed the acceptance test.

Field Incident 3

Here are the results from a recent load test on a 48-volt, 1AVR85-99 East-Penn Deka battery. The battery is rated for a constant discharge of 741 amps for 4 hours, to an end voltage of 1.90 volts/cell or 45.60 volts for the whole string. Test Results #1 shows the battery string hitting the calculated end voltage of 45.60 volts, for an overall battery capacity rating of 80%, but all of the individual cell voltages were higher than the 1.90 volts/cell end voltage. An investigation into these results showed that the installed intercell connectors were rated for discharge currents of less than 375 amps. East Penn rates their connector packages S1 through S4 for different applications or discharge rates.[12] This particular battery had an S1 battery connection package and is rated for a maximum discharge current of 375 amps. The insufficient connector package installed on the battery increased the overall resistance of the battery creating a large voltage drop. This led to a shortfall in the overall performance of the battery capacity. By testing this battery at a higher rate than the connectors were rated for, the test results were inaccurate. This analysis of the battery test results also indicated that the connector package installed was insufficient for the installed application. With only one string of batteries and a power plant load of 527, amps the overall battery run time will be reduced.

We upgraded the connectors to an S2 configuration that is rated for discharge rates up to 750 amps and retested the battery. The battery tested out at 89%.

[11] East-Penn Unigy II I&O manual EPM form 0925 rev 2/02, page 7.
[12] East-Penn Unigy II I&O manual EPM form 0925 rev 2/02, page 7

LOAD TEST #1 RESULTS

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Battery Capacity Test

Date - August 27, 2004

Customer - ____________ Address - ____________

Phoenix, AZ 85013

Site Name - ____________

Site ID - ________ Ticket # - ________

Rectifier Mfg - Peco II Battery Mfg - Deka Unigy II

Model - 687153NB1-11 Model - AVR85-99

Capacity - 1250 Amp Hour - 4200 Ah @ 8hr rate to 1.75 VPC

# of Rectifiers - 25 # of Strings - 1

System Load - 527 Amps Date Code - 851921

Battery Disconnect - Yes Type - Switch Rating - 1800 A

Discharge Data - Mfg. Rate - 741 Amps for 4 hours to 1.90 Volts/Cell @ 77 deg.

Battery Temp (deg. F) - 69 IEEE 'K' Factor - 1.048 45.60 volts Calculated End Voltage

Battery discharge rate - 707 Amps (Mfg rate / 'K' Factor = discharge rate)

Test Date - 8/27/04 Time Started - 0:40 Test % Result - 80%

Power Plant # - 1 Battery String # - 1 Tag # - 1303991

		Elapsed Time / Individual Cell Voltages						
	Time	0:45	1:40	2:40	3:40	3:52		
Cell #	Float V.	5 Min	25%	50%	75%	80%	90%	100%
1	2.25	2.04	2.03	2.00	1.97	1.96		
2	2.26	2.04	2.03	2.00	1.96	1.95		
3	2.26	2.02	2.01	1.97	1.94	1.93		
4	2.26	2.03	2.01	1.98	1.94	1.93		
5	2.25	2.04	2.03	2.00	1.96	1.95		
6	2.25	2.06	2.05	2.02	1.99	1.98		
7	2.25	2.06	2.05	2.02	1.99	1.98		
8	2.25	2.05	2.03	2.00	1.96	1.96		
9	2.25	2.02	2.00	1.97	1.94	1.93		
10	2.25	2.03	2.01	1.98	1.94	1.94		
11	2.25	2.04	2.03	2.00	1.96	1.96		
12	2.26	2.07	2.05	2.03	1.99	1.99		
13	2.25	2.06	2.05	2.02	1.98	1.98		
14	2.26	2.04	2.03	2.00	1.96	1.96		
15	2.26	2.03	2.01	1.98	1.94	1.94		
16	2.25	2.03	2.00	1.97	1.94	1.93		
17	2.26	2.05	2.03	2.00	1.97	1.96		
18	2.26	2.06	2.05	2.02	1.99	1.98		
19	2.26	2.06	2.05	2.02	1.99	1.98		
20	2.26	2.05	2.03	2.00	1.96	1.96		
21	2.25	2.03	2.01	1.98	1.94	1.93		
22	2.25	2.03	2.01	1.98	1.94	1.94		
23	2.25	2.05	2.03	2.00	1.97	1.96		
24	2.26	2.04	2.03	2.00	1.97	1.96		
Total V	54.12	47.84	47.39	46.65	45.83	45.60		

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LIMITING THE RECHARGE CURRENT

If you are recharging the battery with an external constant voltage charger, you can adjust the current limit potentiometer to limit the amount of output current to meet the manufacturer's recommendations. The recommended style of battery charger is a constant voltage / current limiting charging system.

If the plant rectifiers are used to recharge the battery after a discharge test or event, you must calculate the total amount of available rectifier capacity, subtract the load, and this will give you the amount of recharge current available. Example – A Helios Candeo XL with six 200-amp rectifiers installed and a load of 375 amps on the system will give you approx 825 amps of recharge current. This figure is approximate because of the variance with the current limit settings of each rectifier. This could add up to 120 amps to the total recharge current if each rectifier's current limit was set at 220 amps. The industry standard is between 5 and 10% of rectifier capacity. This example would be ok for a 3300 amp-hour battery using a 25% recharge limit. If this amount of recharge current was applied to a 1000 amp-hour capacity battery, you will harm it if the system is not current limited.

Most of the newer power plant controllers are software controlled, and you can program them and set a maximum battery recharge current. This is a setting that cannot be overlooked during start up and PM activity. When performing a battery capacity test, you are onsite and controlling the testing procedure, but what happens during an extended power outage and the batteries run for 8-10 hours? If the recharge current limit is not set properly, you have the potential to do great harm to the string once power is restored. Some of the large, 3 phase UPS manufacturers accomplish this with a built-in battery recharge current limiting circuit. For example, the Liebert 600 series UPS has a battery charge current limiting circuit that can be adjusted between 1% and 25% of the maximum battery discharge current. The factory default setting is 10% and can be adjusted after installation to meet different charging scenarios.[13]

Field Incident 4

I had a technician in NYC in February of 2004 call me, concerned that the battery string he was working on was reading 46 volts. The battery was a GNB 50A13, a 320-amp hour battery. He performed a PM on August 7th of 2003 and the readings were normal at 54V. This was the next PM activity for this site. I asked him if the battery disconnect was open. He said there was none. I asked him to read the plant voltage – 54.1 and the battery terminal voltage – 46.5. I told him this was not possible and to trace the negative battery lead from the main negative to the charge bus. He found an "after market" 120 amp battery disconnect mounted on the rear of the frame in a tripped condition. So what happened between this PM and the last PM? The great East Coast Blackout on August 14, 2003.

What happened is the system was equipped with seven 25-amp rectifiers with only a 32-amp load. The total rectifier capacity is 175 amps (plus an additional 18 amps when you figure in the current limit setting). With a load of 32 amps, that left 161 amps of battery recharge current. The battery supplied the load for 9 hours during the blackout and was almost completely discharged. When power came back on, the rectifiers started back up and tried to recharge the battery with everything they had available, 161 amps going through a 120 amp disconnect – TRIP. Their batteries sat in a complete discharge state for 6 months. This problem went undetected for two reasons: First, they were not monitoring the state of the battery disconnect. Second, they had no power hits from the end of the blackout to the time we showed up to PM the battery. If they had, then their load would have dumped immediately. This was an older power plant that did not have the current limiting option. In this case, the solution was to remove the unnecessary rectifiers. We removed 3 rectifiers from the system, and the customer went from an N+5 configuration to an acceptable N+2 rectifier redundancy configuration.

SUMMARY

You can do serious harm to the battery string if you do not follow the manufacturer's guidelines when recharging. During the recharge process, you need to monitor the recharge current and battery temperature periodically to ensure the battery is recharging properly. You need to understand the effects of battery recharge and discharge current on your equipment when sizing a site. For optimum battery life and performance, maintain a temperature controlled battery room environment, do not undercharge or overcharge the battery, recharge the battery as soon as possible after a discharge event, and perform periodic maintenance per IEEE and the manufacturer's standards. Do not overlook the battery disconnect rating.

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[13] Liebert series 610 guide specs SL-25152 (8/05)