

Battery Event Monitoring of the CRITICAL parameters to assure reliability.

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Abstract

An **event** is defined as “something that happens or is regarded as happening; an occurrence, especially one of some importance; something that occurs in a certain place during a particular interval of time”. In this document we will demonstrate just what “events” need to be monitored to assure you of battery system reliability and predictability (the important parameters) and which can safely be left unmonitored and checked by a knowledgeable person on specific intervals.

It is well understood and documented in numerous professional papers that there is no substitute for a knowledgeable person visiting and inspecting a battery system periodically, even if to just verify the accuracy of what a monitoring system is showing, plus to perform the required visual inspection of the system. Also well understood and just as important, is that there is no substitute for someone that understands what the battery readings mean, to review those values and to report or recommend what actions need to occur to assure system reliability.

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Intro

Of course everyone would like to be able to know everything about their battery systems at all times, such as with a vented battery the O/A voltage, individual cell voltages, individual cell specific gravities, electrolyte levels, cell temperatures, cell to cell connection resistances, battery current and ambient temperature. And with a VRLA battery the O/A voltage, individual cell voltages, individual cell internal ohmic values, individual cell temperatures, cell to cell connection resistances, battery current, and the ambient temperature.

All of those are desirable items, but which are the most critical that a change in that item needs to be known and understood ASAP? Everyone well understands that no matter how extensive a monitoring system is, you still need to periodically have a knowledgeable stationary battery technician physically looking at the battery and verifying the information that is coming from the monitor. There are no exceptions to this need. The interval for human interaction is dependent upon the user's desire and decision on importance of the system. In some systems this could be as frequent as once per shift and with other systems it could be once per year. It really is up to the user to determine based upon a number of variables, to include the cost of the system or service.

A human can, in addition to measuring and recording the over-all voltage, the individual cell voltages, SG if vented and internal ohmic values if VRLA, cell or electrolyte temperatures, strap resistances, battery current, and ambient temperature, actually look at the battery for signs of leakage, or corrosion, or other abnormalities. They also can observe the condition and color of the plates, the sediment and other items in a vented cell. A machine cannot do that.

What is it we do not want to occur?

The following are some pictures of events that we want to prevent, and that were all preventable if someone had been "minding the store", in other words looking at a monitor. Some of these are caused by thermal runaway, and some by negligence. Each is unique, but not very rare as they continue to occur.

Not this rapidly expanding building



This was a Telecom site in a residential area in a state that normally has summer temperatures of 100 or higher Fahrenheit. The battery was a single string 48 volt VRLA. There was a single wall mounted air conditioner. The air conditioner failed and when it was removed and taken to be repaired, plywood was attached to the opening to keep out unwanted things (people, bats, birds???)

Within days of the removal of the air conditioner the building exploded. There was some slight damage to nearby homes but no one was injured.

The investigation determined that the temperature inside of the building was above 140 degrees F. The float voltage was still set at 54.0 volts, and with 140 degrees the batteries were off gassing at a substantial rate. With the size of the building it did not take long to create an explosive atmosphere, and then something made an arc, and the rest is this picture. This could have been prevented if it had been monitored off site, as the observer would have seen the conditions occurring.

Nor this raising the roof event (it also had rapidly expanding walls)



This picture is of a data center in Sacramento that had been vacated and no one was minding the building, but the power had been left on and the UPS was keeping the batteries charged. There is no information available about the HVAC as to whether it was operational or not. There monitoring equipment for combustible gas was working however; as the neighbors heard the alarm going off for numerous days before the explosion.

Again it was lucky that no one was hurt. As can be seen there was extensive damage. If this system had been monitored by off-site personnel this event could have been prevented as they would have observed the increasing float currents long before this occurred, and have taken action to prevent this event.

Or this thermal runaway



This could have been prevented with monitoring from off site as the increase in float current and cell temperature would have been observed.

What items need to be monitored?

So, if a person needs to physically inspect a battery on some selected interval just what items are critical to be monitored the rest of the time? I propose that the following four items are all that are really needed to be monitored to assure the user of an operable battery system and to provide advance alerts of conditions that will negatively impact the battery system. The event that needs to be watched is any change from the normal known good or acceptable value/s.

1. Over-all battery voltage
2. Battery current
3. Ambient temperature
4. Cell/battery temperature

Why just those four items? Because those items will inform you of any conditions that are affecting your battery and will allow you to take pro-active actions when required, to protect your system. Let's look at each of these four items and see how each, either individually and/or in conjunction with one or more, of the other parameters will provide the protection required to assure you of operability and reliability, plus verification that you are meeting the requirements of the manufacturer's warranty.

1. Over-all battery voltage.

With every battery chemistry there is a manufacturer's recommended voltage range per cell at a specific cell temperature, which is normally 25C (77F).

Changes in this value can alert you to a number of issues. Any change in 0.1 to 0.2 VDC should trigger an alert. This value of change could be caused by, or inform you of, or be a benefit to one of the following.

- Ac power failure
- DC load above the charger/rectifier system limit
- Charger/rectifier system malfunction
- Battery on discharge
- Cycle counts and charging voltages for warranty purposes
- Depth of the Coupe-De-Foute, under system load

2. Battery Current

Every individual battery model has specific discharge current capabilities, and float current requirements at differing temperatures that can be used to understand the batteries capabilities, or condition. A change in current of 0.1 to 0.2 amp should send an alert, for the person that is responsible for the monitor to determine if there is a need for actions to be taken and the timeliness of that action or actions.

Discharge current alert can inform you of the following

- Loss of Ac to the charger/rectifier system or the site
- DC Load that is above the charger/rectifier system capability
- Charger/rectifier system malfunction
- Actual site load due to the battery being on discharge
- Potentially be used to perform a capacity calculation

Float current and recharge current alert can inform you of the following

- When the battery is fully charged following a discharge event
- Current limit of the charger/rectifier system
- If the internal conditions are changing negatively
- If the float current is proper for that specific model battery
- Of impending thermal run-away

3. Ambient temperature

The ambient temperature should alert with any 1 degree of change. This level of information can inform you of the following

- What is the actual ambient temperature near the battery
- Is the HVAC working
- If the over-all voltage is correct for the actual ambient
- In a small building, if someone enters or leaves the building

4. Cell/battery temperature

The cell/battery temperature should alert with any 1 degree of change. This level of information can inform you of the following

- An over charging issue
- Internal cell degradation
- Conditions that are leading toward thermal run-away
- Charger/rectifier issue (such as capacitor failures)

With every battery that is manufactured, each has its very own specific internal values, performance characteristics, float voltage requirements, recommended and operational temperature range, temperature compensation requirements, and normal float current requirements. For each individual model, all of these items relate to and have an effect on each other.

For example: a lead acid battery that is designed to operate at 25C (77F) with an acceptable float voltage range of 2.22 to 2.26 VPC with a recommended value of 2.25 VPC, and the float voltage average is 2.25 VPC but the normal ambient temperature is 18C (65F) is actually being undercharged, as the temperature compensated voltage that a cell would see is 2.215 volts, not 2.25 volts and the performance will be degraded.

If you reverse the temperature in this same situation with an average per cell voltage of 2.25 volts but now the average temperature is 32C (90F) the voltage the cell is seeing is 2.285 volts per cell which is over-charging the cells. Which will increase the float current, the off gassing, over charge the plates, lead to accelerated plate growth, and early life failure.

Battery Event Monitoring

A battery event monitor must continuously be taking measurements of those four parameters, and sending those readings over the internet to its server. The server reports on any changes observed that trigger an alert function. An alert is sent to the battery expert that is responsible for reviewing this information who then reviews the information and reports on the event as needed. For security reasons there is only one way communication from the onsite monitor to the server. No access is allowed from outside into the monitor. All changes to alarm values or set points takes place at the server.

Now let's discuss how a Battery Event Monitor can provide all of the information required to predict degradation, important changes, and provide advance warning to any items needing action. Well what notifications would we want to be sent to us, so that we can know what is going on with the battery. I propose that the following notifications with specific parameter measurements would cover all events of interest.

- Is the monitor functioning, on line, off line, or disabled
- What is the over-all voltage of the battery? Is it changing? Is it undergoing a discharge event? Is it recharging following a discharge event? Is the voltage correct for the temperature?

- What is the battery temperature? What is the ambient temperature? What is the temperature differential between the battery and the ambient?
- What is the float current? What is the discharge current during a discharge? What is the recharge current following a discharge event? When does the float current return to its pre-discharge condition?

The most important thing with any monitoring system is that when the system is installed there must be a complete set of battery values gathered with instrumentation other than the monitoring system. This is so that you will know what the correct values are for each cell/jar in that particular battery. Of course these must be the fully charged values, along with the "normal" float current requirements. For any readings to be meaningful you MUST know what a good value is for that particular battery and what you are starting with. If you try to use a monitor to compare starting values that are bad for that particular cell model to some set of value changes you will not obtain the protection or warning that you are looking for.

In addition, the values that you observe from the monitor must be real and accurate. If you try to rely on data that is not accurate, and try to base your decisions on changes from that inaccurate data you are gambling that the real values (not the inaccurate ones you see from the monitor) are in fact within a safe range for your application.

What also is critical if your goal is to prevent unexpected battery failure is that you must know the capacity or capability of the battery being monitored. This means that you need to follow the applicable IEEE standard for the particular type battery that the monitor is going to be installed on.

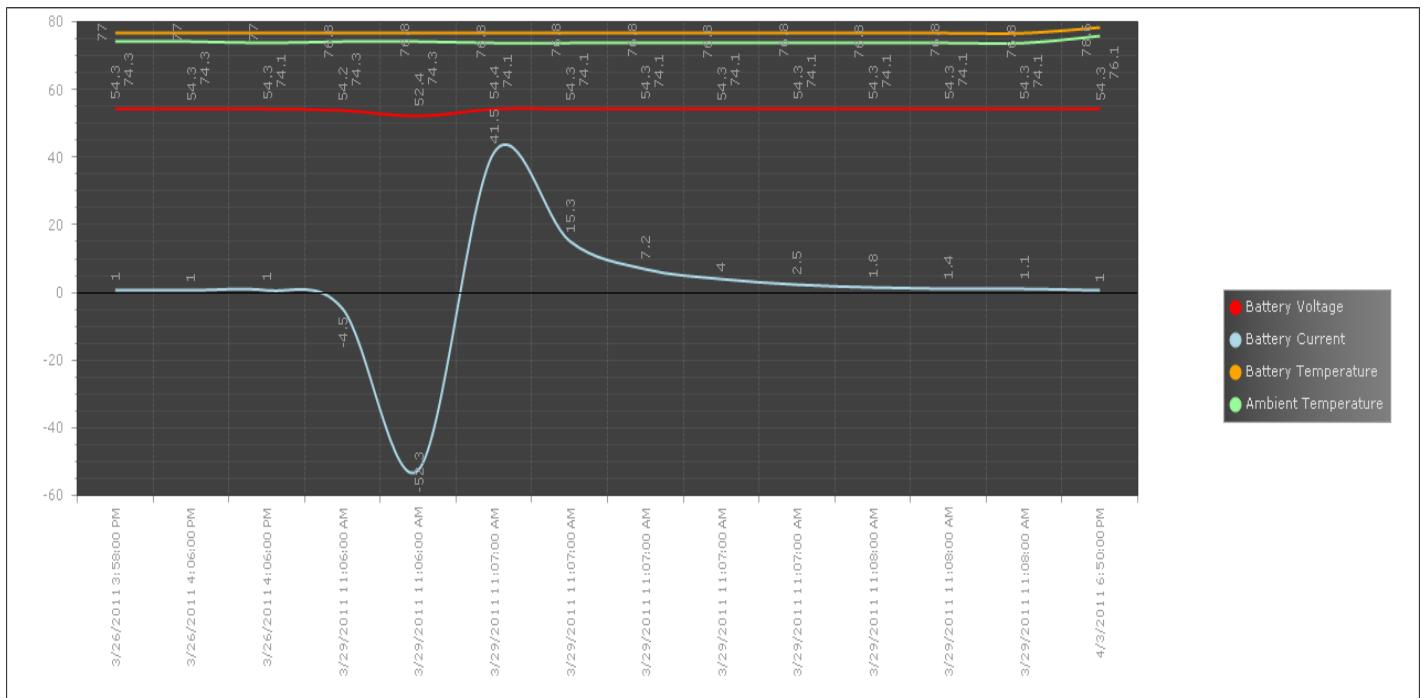
For both the gathering of the values from each battery and for the procedures for load testing of each battery, the following are the applicable documents to be followed.

With Vented lead acid that would be IEEE 450-2010. With VRLA that would be IEEE 1188-2005. With Vented Nickel Cadmium that would be IEEE 1106-2005.

Visual tracking of changes

There are two basic formats that most people like to see value formatting in. The first is the simple chart which shows when each item changes, where you can see all of the changes being monitored over time in the same place, as shown below.

With the following chart it is easy to see that on 3/29/11 that there was a short power interruption that put the site load onto the battery for less than one minute. At 11:06:37 AM power was lost and that the maximum discharge current was 52.3 amps and that the lowest voltage during the discharge was 52.4 volts. By 11:07:02 AM the voltage had returned to 54.2 and the maximum charge current was 41.5 amps. It can also be observed that by 11:08:52 AM the float current had returned to within 0.2 of an amp of where it was prior to the discharge event. This was a very short power hit. This same information when viewed in the log format, lists the time of each event to the second.



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The next type of reporting format is shown below, where each change is an individual line item. I removed the majority of the time stamps for this display as there was an alert for every single degree change of the battery or of the ambient, or 0.1 of an amp current change. There was no change in the battery voltage, just in the ambient and battery temperatures and a slight change in the float current as the battery got hotter. The cause of all of the alerts over this four month period was due to repeated failures of the air conditioner. Without the air conditioner the equipment in room caused the ambient temperature to increase which over time caused the battery temperature to rise. The highest observed battery temperature was 100.9F on 8/4/2011.

Time Stamp	Volts	Current	Battery Temp	Ambient Temp	Event
8/5/2011 2:36:06 PM	54.3	1.2	86.5F	75.7F	Current Change
8/5/2011 11:18:07 AM	54.3	1.6	87.4F	75.6F	T-battery Change
8/5/2011 4:36:56 AM	54.3	1.9	91.0F	77.2F	Current Change
8/4/2011 11:36:39 PM	54.3	2.3	94.8F	80.6F	T-ambient Change
8/4/2011 10:09:24 PM	54.3	2.4	97.3F	84.2F	T-ambient Change
8/4/2011 9:05:45 PM	54.3	2.5	99.7F	88.5F	T-ambient Change
8/4/2011 8:35:09 PM	54.3	2.5	100.9F	92.1F	T-ambient Change
8/4/2011 8:21:41 PM	54.3	2.5	101.7F	93.9F	T-ambient Change
8/4/2011 2:52:35 PM	54.3	2.4	101.3F	95.7F	T-ambient Change
8/3/2011 9:29:44 PM	54.3	2.2	98.2F	94.1F	Current Change
8/3/2011 4:30:37 PM	54.3	1.9	96.6F	92.8F	T-ambient Change
8/3/2011 12:16:28 PM	54.3	1.8	95.4F	91.0F	T-battery Change
8/2/2011 10:47:00 PM	54.3	1.5	91.8F	90.7F	T-battery Change
8/2/2011 9:41:58 AM	54.3	1.1	85.3F	84.9F	T-ambient Change
8/2/2011 3:55:28 AM	54.3	1.1	82.6F	81.3F	T-ambient Change
8/2/2011 2:46:57 AM	54.3	1.1	81.7F	79.5F	T-ambient Change
7/27/2011 11:33:14 PM	54.3	1.0	81.5F	75.9F	T-ambient Change
7/27/2011 11:13:15 PM	54.3	1.1	81.7F	77.7F	T-ambient Change
7/26/2011 2:33:12 AM	54.3	1.4	84.7F	76.6F	Temp. Differential
6/21/2011 3:47:53 PM	54.3	1.2	85.2F	79.6F	T-battery Change
5/12/2011 4:38:01 PM	54.3	1.5	82.9F	77.4F	Current Change
4/4/2011 6:22:56 AM	54.3	1.2	76.4F	75.2F	Floating

It is very important to understand that with the battery at no time was it in danger of thermal runaway as the float current never contributed to the rise in the battery temperature. The entire temperature rise was due to the increasing ambient each time that the air conditioner failed. Because I removed hundreds of lines of data you cannot see each individual change in this amount of space. Over this four month period there were no power outages or charger failures as at no time did the battery voltage stray from its setting of 54.3. With the above battery, if someone had walked into the room when the battery was at 100+ degrees, they might have mistook the situation as a thermal runaway and ordered a replacement battery, which would have been a complete waste of money.

All information that is sent from each battery monitor is sent off site to a central server where the information is processed and stored, and all alerts or alarms are issued from. All alarms should be reviewed by a battery expert before they are sent to a site person. This will reduce the number of notices that the user is receiving. Of course if the user wants to be alerted to every change this can be provided. This stored information should be available from anywhere, and the user should be able to look at the data from when the monitor was first installed up until whatever the present time is.

Scenario One

Remote small climate controlled telecom site, with a single 48 volt (24 cells) 750 AH VRLA battery installed with two 50 amp rectifiers. Site load of 35 amps at 54.0 volts (1,890 watts), with a low voltage cut off of 44.0 volts. Normal float voltage of 54.0 volts, float current of 0.45 of an amp, room ambient of 23.8 C (75F), normal cell temp is 24.4 C (76F).

Off site power is lost to the site. As soon as the over-all voltage changes by 0.1 of a volt the server sends an alert and continues to send alerts on every 0.1 volt change. This will occur within seconds of the loss of power to the rectifiers. In addition as the current flowing through the battery changes by 0.1 of an amp, which will occur instantaneously as the battery goes from charging to discharging, it alerts of what that current is and at what time intervals. It also will alert to any temperature changes.

The loss of power to the site continues for 6 hours at which time the battery voltage is at 47.6 volts, and the discharge current is 39.7 amps. Ac power is restored, the server sees the change in voltage and in current from discharging to re-charging as the rectifiers return to service, and the battery voltage begins to increase. Both 50 amp rectifiers should go into current limit in order to support the site load and to re-charge the battery string, which would mean that there should be approximately 80 amps available for the initial re-charge current. If the initial re-charge current is about 10 - 15 amps that will tell you that only one rectifier returned to service. But for this example let's assume that both rectifiers returned to service and are limited to 50 amps of output. Plus let's assume that the initial inrush of current that goes through the battery is 65 amps.

Of course the over-all voltage will return to @ 54.0 volts quite quickly, and at the same time the server will continue to send notifications on changes in current, voltage and temperatures. In this scenario we would expect that within 12 – 24 hours the battery would be fully recharged and ready for its next operation. It might take a couple days for the float current to return to the 0.45 of an amp that it was originally at, but the battery for all intents or purposes will be 95%+ recharged within 24 hours or less.

After all the battery really only delivered about 240 amp hours, and with @ 65 amps available for recharge usage, this battery should be recharged quite quickly. Yes, we all understand that as the cells become re-charged the current will decline, but within 24 hours or less it will be recharged.

With this scenario, in addition to knowing just how the battery performed at the actual site load, you also can verify rectifier operation and current limits, plus possibly be able to perform a capacity calculation. In addition, as the HVAC returns to operability you will be able to verify that it actually is functioning as you observe the temperature change of the ambient as it returns to pre power outage values.

Scenario Two

Two parallel strings of 60 cells each in a switchgear/control application. Float voltage of 134.4 volts on each, string "A" has a float current of 1.3 amps and string "B" a float current of 1.5 amps. Ambient of 25C (77F) cell temps. Of 26 – 27C (78-79F).

Over time string "B" starts sending alarms that the float current is raising and that the differential between the cell temp and ambient in that string is growing, while string "A" is remaining stable.

These alerts will tell a knowledgeable person that there is some sort of degradation in string "B". If these were VRLA batteries it could be that the cells are drying out in that string, or with either VRLA or VLA there is a possibility of a path to ground on that battery. Either way, a decision will need to be made as to the timeliness of the corrective actions. Remember that if they are connected in parallel the over-all voltage will be the same with either battery, no matter what.

Also if there is a discharge event you will observe that one string is providing a larger portion of the current. This also will alert you to issues that need to be corrected.

Scenario Three

A single 60 cell battery at a power generation station, there is a loss of Ac power and the unit goes onto the battery for support. All works as planned and the battery supported all required loads until the unit coasts to a correct shutdown. This is a good thing, but is there anything that we should see during this?

The server of course will record the currents, and the over-all voltage throughout the event. In review of the data the person reviewing the alerts notices that the voltage dropped substantially lower than it should have and in fact had almost reached the low voltage cut-off before beginning its recovery. This should raise a large red flag, as you need to determine just why that occurred. Is it internal degradation, a bad connection or connections in the circuit? No matter what, you need to investigate and take the necessary actions.

Conclusion

These were just a few examples, and I am sure that those reading this can picture many others. I firmly believe that by continuously monitoring just those four values, and alerting on change, that all normal unexpected occurrences can be eliminated, and that those four items when monitored by knowledgeable personnel can prevent failure to any system.

I keep mentioning "knowledgeable" personnel due to the fact that I believe that the monitoring should be the primary responsibility of someone off site that is a stationary battery expert, and the user (or site contact) be a secondary or parallel alert. There are too many horror stories about where there had been repeated "nuisance" alarms from the battery room, and the site people finally disarmed the alarm because it was always erroneous, and then there came a real battery issue, but the alarm was disconnected and the results proved disastrous.

I thank you for your attention and look forward to any questions or comments.

If you would like to discuss this idea in more detail following this conference, please feel free to contact me at any time.