WHITE PAPER

Battery maintenance and replacement - PowerValue

A guide how to keep PowerValue batteries healthy and durable
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A guide to keep PowerValue batteries healthy and durable

The battery represents one of key parts of a UPS system, with no doubts the most sensitive component. Not only a precise and well-balanced choice of the battery has to be taken into account when dimensioning a UPS system (weight, dimensions, performances, runtime…) but also maintenance and replacement operations have to be well planned and managed. In fact for the ABB single-phase UPS PowerValue 11RT the only maintenance operation recommended on the device concerns the batteries themselves.

Battery facts
The VRLA batteries are used popularly in single-phase UPS systems.

They are basically made by spongy lead (Pb) and lead dioxide (PbO₂) plates that are placed in an electrolyte solution of diluted sulfuric acid.

The reaction of lead and lead oxide with the sulfuric acid electrolyte produces a voltage.

Battery discharge happens by means of connecting a load between the two battery poles.
Battery charge happens by means of applying a higher voltage between the two battery poles from an external source (battery charger).

When fully charged, the battery can be chemically described as it follows:

\[ \text{PbO}_2 + \text{Pb} + \text{H}_2\text{SO}_4 \]

As the battery discharges, the active material on both plates converts to PbSO\(_4\) (lead sulfate), and the electrolyte converts to almost pure water.

The amount of material in the plates which participates in the reactions (charge and discharge) is defined as the active material, and the energy that can be stored is directly proportional to the amount of active material available.
Why batteries fail prematurely in a UPS

The battery is the most vulnerable part of any single phase UPS system, regardless of its capacity, topology or brand. The battery is ultimately at the heart of the UPS in terms of reliability. Understanding the causes of battery degradation is the way to prevent it and maintenance actions are fundamental to ensure highest system availability.

The reasons why most batteries fail prematurely in a single phase UPS system can be summarized as it follows:

a. Excessive cycling
b. Improper charging and discharging
c. Lack of temperature control
d. Operational issues
e. Improper battery storage conditions

The user plays an important role on proper management of most of the points above.

Details are hereunder described:

a. Excessive cycling
The number of charging and discharging cycles will affect the service life of the battery.
Every time a battery cycles (a discharge followed by a recharge), the electrochemical generator is working, which involves converting acid and paste. As the paste on the positive grid changes from PbO₂ to PbSO₄, there is a large increase in volume. The more the paste is expanded and then later contracted, the more the battery will suffer wear and tear.
Moreover, cycling a battery accelerates corrosion of the grid structure, which unavoidably leads to a shorter lifetime.

b. Improper charging and discharging
The lifetime of a battery can be greatly affected by the current and voltage control on the battery during charge and discharge cycles.
Overcharging leads to loss of water in flooded cells and to dry-out in VRLA cells.
Undercharging results in a permanent loss of capacity. It will also cause a loss of active material by the negative plates.

To avoid these drawbacks, ABB PowerValue UPS properly manages and controls, under all working conditions, current and voltage limits through the internal CPU.
In addition, a typical UPS working in battery mode, discharges the battery up to 80% depth of discharge if minimum cut off voltage is not reached first. As noted in the following picture:

![Cycle Service Life Diagram](image)

If the battery is operated in a 25°C environment it should provide about 300 full discharge/recharge cycles before it requires replacement. In most UPS applications, a full discharge to low battery cutoff is a rare event; thus, cycle service life would never be an issue. However, should a UPS be used in a high temperature environment where it was discharged on a daily basis, then the batteries would have to be replaced every six months or less.
c. Lack of temperature control

It is well known that all lead-acid batteries will have a shorter life when operated at a higher temperature. This is the case no matter what type lead-acid battery it is and no matter who manufacturers them. According to Arrhenius, for every 10°C increase in temperature (above ideal condition) the battery life would be halved. Therefore, as an example, if the life is 15 years at 25°C then at 35°C the life will be 7.5 years. The Arrhenius equation is only valid between about 15°C and 40°C for operational batteries.

But why exactly is the life reduced? There are many interacting electro-chemical effects but one of the main reasons is that for any given constant voltage that is applied to the battery by the float charger there will be a resultant float current. Lead-acid batteries will accept more current if the temperature is increased and if we accept that the normal end of life is due to corrosion of the grids then the life will be halved if the temperature increases by 10°C because the current is double for every 10°C increase in temperature. It has also been shown that evaporation of water through the container walls occurs and if the temperature is increased then evaporation will also increase. This may result in drying out of some batteries of the VRLA AGM and VRLA GEL type. However, this is a complex subject that cannot be easily calculated and applied to give a predicted life. In any case, good quality lead-acid batteries will not normally fail due to drying out. Drying out is not relevant to vented types and we can use the Arrhenius equation to give an estimate of the life when the operational temperature is different than the design temperature.

In Europe it is common for battery lives to be quoted when operating at a continuous temperature of 20°C. If the temperature is 10°C for 3 months, this will not reduce the overall life by half but only a percentage of the expected 20°C life. However, operating at 21°C and not at 20°C for the entire life will reduce the life by almost 10%. So we should separate “design life” and “real life”. For example, a VRLA AGM battery may be quoted as having a design life of 10 years but the real life, even when operated continuously at 20°C, will be nearer 8 years.

In addition, if the battery is subjected to particularly high temperatures or if thermal management is poor, the battery may go into thermal runaway. If this occurs, the complete battery will be destroyed. Thermal runaway can occur within a very short time.

**ABB PowerValue UPS integrate a temperature compensated charging equipment to avoid the risk of thermal runaway.**

The graph below gives a practical example to estimate the life of a battery when operated on float systems at different operating temperatures. The graph may be used to estimate the effect of different daily or monthly operating temperatures. E.g., one day at 30°C will have the effect of 2 days at 20°C.
From the chart below we can see that for every year the battery has aged 437 days and not 365 days. Therefore if the battery design lifetime is 5 years (1'825 days), in according with IEC 60896, the real lifetime is $1'825 / 437 \approx 4$ years only.

<table>
<thead>
<tr>
<th>Month</th>
<th>Avg temperature (°C)</th>
<th>% of nominal life</th>
<th>Aging effect</th>
<th>Aged days within the month</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20.5</td>
<td>95</td>
<td>1.05</td>
<td>31.58</td>
</tr>
<tr>
<td>2</td>
<td>21</td>
<td>92</td>
<td>1.09</td>
<td>32.61</td>
</tr>
<tr>
<td>3</td>
<td>22</td>
<td>87</td>
<td>1.15</td>
<td>34.48</td>
</tr>
<tr>
<td>4</td>
<td>23.2</td>
<td>80</td>
<td>1.25</td>
<td>37.50</td>
</tr>
<tr>
<td>5</td>
<td>25.3</td>
<td>70</td>
<td>1.43</td>
<td>42.86</td>
</tr>
<tr>
<td>6</td>
<td>26</td>
<td>65</td>
<td>1.54</td>
<td>46.15</td>
</tr>
<tr>
<td>7</td>
<td>25.2</td>
<td>70</td>
<td>1.43</td>
<td>42.86</td>
</tr>
<tr>
<td>8</td>
<td>23.8</td>
<td>77</td>
<td>1.30</td>
<td>38.96</td>
</tr>
<tr>
<td>9</td>
<td>22.5</td>
<td>85</td>
<td>1.18</td>
<td>35.29</td>
</tr>
<tr>
<td>10</td>
<td>21.5</td>
<td>90</td>
<td>1.11</td>
<td>33.33</td>
</tr>
<tr>
<td>11</td>
<td>20.5</td>
<td>95</td>
<td>1.05</td>
<td>31.58</td>
</tr>
<tr>
<td>12</td>
<td>20</td>
<td>100</td>
<td>1.00</td>
<td>30.00</td>
</tr>
</tbody>
</table>

Total aged days per calendar year 437.21
d. Operational issues

Discharge frequently without full recharge on time

A near fully discharged cell will likely get damaged if not recharged on time. As the battery discharges, the electrolyte starts to alter from an acid solution into water. Lead dissolves in water, and the materials on the plates material mix with water to form lead hydrate. Lead hydrate causes the plate surfaces to turn into white and, as it is conductive, it may cause a short circuit between the plates, irreversibly damaging the battery.

Over discharge

Over discharge causes abnormal expansion of the active material on the plates, which leads to permanent damage and also recharging problems. This can happen in lightly loaded UPS systems that experience an extended power outage.

**ABB PowerValue UPS has a specific protection to avoid this phenomenon.**


e. Improper battery storage conditions

If stored without recharging, VRLA batteries self-discharge at a temperature specific rate over time. If allowed to discharge to a level below 80% depth of discharge, irreversible damage may occur inside the battery. The damage is caused by deposition of lead sulfate on the surface and in the pores of the active material of the batteries' lead plates. The capacity retention chart below:

![Capacity Retention Characteristic](image)

- No supplementary charge required (carry out supplementary charge before use if 100% capacity is required)
- Supplementary charge required before use. This supplementary charge will help to recover the capacity and should be made as early as possible.
- Supplementary charge may often fail to recover the capacity. The battery should never be left standing until this state is reached.
shows the effects of the self-discharge rate at an ambient storage temperature. Assuming the battery was fully recharged when stored at 25°C, it is recommended to recharge it every 6 months. If stored in a 40°C environment, the battery must be recharged every 2 months.
How to maintain correctly the batteries in single phase UPS systems: good practices

For an optimum reliability, it is recommended that the battery of the UPS is quarterly checked. In general the kind of inspections and the related actions to be overtaken during periodic maintenance include:

a. Visual battery inspection
b. UPS battery capacity test
c. Environmental temperature control
d. Check the floating charger of the battery

a. Visual battery inspection

Typical problems that might be discovered with a simple visual inspection are the following, linked with root causes and actions to solve/mitigate them:

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Possible causes</th>
<th>Corrective actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover/container cracked</td>
<td>Handling or impact damage, cell dry out or ground fault, Potential internal gas ignition</td>
<td>Replace the damaged unit</td>
</tr>
<tr>
<td>Cover/container explosion</td>
<td>Ignition of cell’s internal gases due to an external source</td>
<td>Replace the damaged unit</td>
</tr>
<tr>
<td>Signs of overheating on battery container</td>
<td>Cracked container with possible leakage of electrolyte, Ground fault</td>
<td>Clear the ground fault and replace the defective unit, Evaluate the balance of the string(s)</td>
</tr>
<tr>
<td>Permanently deformed (swollen) container</td>
<td>Thermal runaway possible caused by a high temperature environment, overcharging, excessively high recharge current</td>
<td>Replace the battery system and correct the issue leading to the thermal runaway condition</td>
</tr>
<tr>
<td>Corrosion at terminals</td>
<td>Residual electrolyte from manufacturing or electrolyte leakage from the battery terminals</td>
<td>Disassemble connections, clean, coat connecting surfaces and terminals area and reassemble appropriately the connections</td>
</tr>
</tbody>
</table>
b. UPS battery capacity test

Using the UPS

1. Plug-in the AC input power but do not switch on the UPS. The UPS batteries will charge in this way, no need to start the UPS. Leave it charging over night
2. Perform a discharging cycle with a dummy load such as a PC or a 120W bulb until the automatic low battery cutoff kicks in (= battery considered discharged)
3. Repeat step 1
4. Does the battery capacity return to the nominal value after performing the actions above? If not, the battery could have got damaged. In such a case, the battery shall be replaced

Using a DC power supply

1. Make use of a DC Power supply to charge the battery at 14.7 Vdc (keeping limited the charger current according the battery capacity → typically the charger current shouldn't exceed 0.25 CA) per battery over the night (>16 hours)
2. Install the battery in the UPS and discharge the battery with a dummy load such as a PC or a 120W bulb until the automatic low battery cutoff kicks in (= battery considered discharged)
3. Repeat step 1
4. Does the battery capacity return to the nominal value after performing the actions above? If not, the battery could have got damaged. In such a case, the battery shall be replaced

Note. When the battery reaches the 80% of its rated capacity, the aging process accelerates. It is wise to replace the battery at this stage.

IEEE, in fact, defines the end of useful life for a battery as the point when it can no longer supply the 80% of its rated capacity in Ampere-hours.

Because the relationship between the battery capacity and load autonomy time is not linear, a 20% reduction in capacity results in a much greater loss in the backup time.

For example, a UPS battery that supports a full load for 15 minutes at early stage of its life, will support the same load for about eight minutes only when it approached its end of life.

c. Environment temperature control

1. Protect UPS from heat sources such as sunlight, portable heaters, etc.
2. The UPS shall be installed in areas with temperature control
3. Effective active and passive ventilation of the environment has to be taken into account
4. If the battery is stocked in a high temperature environment, a recharging action should follow
d. Check the floating charger of the battery
As batteries come to the full charge, the battery voltage rises until approaching the charger output voltage and consequently the charging current decreases.
It is a good practice to check and record the float voltage across the whole battery with an accurate digital voltmeter.
Normally, the difference between the float charger voltage and the battery terminal voltage is no more than 480mV for a 12V rated battery, given the battery is fully charged.
ABB PowerValue battery products

The top quality rack-tower configurable ABB PowerValue 11RT comes with a comprehensive set of UPSs with and without internal batteries. In both instances, External Battery Modules (EBMs) are available. EBMs are battery packages already installed in a resilient case, suitable for both rack or tower installations; hot-swappable, it’s easy to connect them to a brand new or existing UPS system, up to 4 EBMs per single UPS. Each EBM is dedicated to a specific UPS.

At a glance, 11RT family is made by the following items:

<table>
<thead>
<tr>
<th>Power (kVA)</th>
<th>Internal batteries configuration</th>
<th>EBM battery configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kVA B</td>
<td>1 x 3 x 7.2 Ah</td>
<td>(2 x 3) x 7.2 Ah</td>
</tr>
<tr>
<td>1 kVA S</td>
<td>-</td>
<td>(2 x 3) x 7.2 Ah</td>
</tr>
<tr>
<td>2 kVA B</td>
<td>1 x 4 x 9 Ah</td>
<td>(2 x 4) x 7.2 Ah</td>
</tr>
<tr>
<td>2 kVA S</td>
<td>-</td>
<td>(2 x 4) x 7.2 Ah</td>
</tr>
<tr>
<td>3 kVA B</td>
<td>1 x 6 x 9 Ah</td>
<td>(2 x 6) x 7.2 Ah</td>
</tr>
<tr>
<td>3 kVA S</td>
<td>-</td>
<td>(2 x 6) x 7.2 Ah</td>
</tr>
<tr>
<td>6 kVA</td>
<td>-</td>
<td>1 x 15 x 9 Ah</td>
</tr>
<tr>
<td>10 kVA</td>
<td>-</td>
<td>1 x 20 x 9 Ah</td>
</tr>
</tbody>
</table>

It’s thus possible to reach the maximum flexibility in the configuration and to expand the system runtime.
A full set of spare battery kits is available for PowerValue 11RT (batteries not included). Each battery kit consists of a battery plastic tray and links to connect the batteries in series and thus to the UPS battery connector. Replacement battery kits are available for PowerValue 11RT EBM’s, too (batteries not included)

PowerValue 11RT 1 kVA B – replacement battery pack
PowerValue 11RT 2 kVA B – replacement battery pack
PowerValue 11RT 3 kVA B – replacement battery pack

For more information about ABB PowerValue and batteries, please visit:
or simply contact your regional sales manager
How to replace the internal batteries

The PowerValue 11RT internal batteries (for 1-3 kVA B models) have a design lifetime of 3-5 years; according to the usage of the UPS, it might be necessary to replace the batteries at the end of the design lifetime or even earlier.

So what to do when the internal battery string is tested to be worthy of a replacement? Will I get a load drop? Shall I need to plan an expensive service intervention? Do I need to be a battery expert? Nothing of this at all. PowerValue 11RT internal batteries are hot swappable and easy to replace and this operation doesn’t require the intervention of qualified engineers. The following instructions aim to guide even a not expert person to a safe and correct replacement of internal batteries.

Prior than approaching a battery replacement operation we invite you to:

- carefully read the safety instructions reported in the User Manual
- make sure the UPS is not running in battery mode
- prepare in advance the replacement battery package (for this step you might need PowerValue battery spare kits)
- make sure the new batteries are fully charged
- replace batteries with same type of batteries or contact ABB for more information about compatible batteries
- follow local regulations in order to discard properly the used batteries

The following steps show how to replace the internal batteries:
1. Remove the LCD box and the screws on the front panel

2. Slide and pull the front panel to the left to remove it
3. Disconnect the cables A and B

4. Remove the inner battery bracket, on the right side
5. Pull out the used battery pack and place it on a flat surface

6. Install the new battery pack, screw on the battery bracket and reconnect the battery cables (A and B)
8. Re-install the front panel back to the UPS
How to configure the external battery modules

After installing a new external battery package, it’s necessary to configure correctly the UPS according to the following procedure:

a. Standard EBM value setting through LCD display and RS232 (M is the total nr of standard EBM connected, $1 \leq M \leq 9$)

<table>
<thead>
<tr>
<th>UPS Model</th>
<th>LCD display (path: Settings→Password (USER)→External battery modules)</th>
<th>RS232 (command: SASV03[value]&lt;cr&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPS PowerValue 11 RT 1 kVA B</td>
<td>M</td>
<td>$2M + 1$</td>
</tr>
<tr>
<td>UPS PowerValue 11 RT 1 kVA S</td>
<td>M</td>
<td>$2M$</td>
</tr>
<tr>
<td>UPS PowerValue 11 RT 2 kVA B</td>
<td>M</td>
<td>$2M + 1$</td>
</tr>
<tr>
<td>UPS PowerValue 11 RT 2 kVA S</td>
<td>M</td>
<td>$2M$</td>
</tr>
<tr>
<td>UPS PowerValue 11 RT 3 kVA B</td>
<td>M</td>
<td>$2M + 1$</td>
</tr>
<tr>
<td>UPS PowerValue 11 RT 3 kVA S</td>
<td>M</td>
<td>$2M$</td>
</tr>
<tr>
<td>UPS PowerValue 11RT 6 kVA</td>
<td>$M^*9/5 – 1$</td>
<td>$M^*9/5$</td>
</tr>
<tr>
<td>UPS PowerValue 11RT 10 kVA</td>
<td>$M – 1$</td>
<td>$M$</td>
</tr>
</tbody>
</table>

b. Settings with a customized battery pack of N Ah capacity, through LCD display and RS232 (take only the integer part)

<table>
<thead>
<tr>
<th>UPS Model</th>
<th>LCD display (path: Settings→Password (USER)→External battery modules)</th>
<th>RS232 (command: SASV03[value]&lt;cr&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPS PowerValue 11 RT 1 kVA B</td>
<td>$N/(7.2*2)$</td>
<td>$N/7.2 + 1$</td>
</tr>
<tr>
<td>UPS PowerValue 11 RT 1 kVA S</td>
<td>$N/(7.2*2)$</td>
<td>$N/7.2$</td>
</tr>
<tr>
<td>UPS PowerValue 11 RT 2 kVA B</td>
<td>$N/(9*2)$</td>
<td>$N/9 + 1$</td>
</tr>
<tr>
<td>UPS PowerValue 11 RT 2 kVA S</td>
<td>$N/(9*2)$</td>
<td>$N/9$</td>
</tr>
<tr>
<td>UPS PowerValue 11 RT 3 kVA B</td>
<td>$N/(9*2)$</td>
<td>$N/9 + 1$</td>
</tr>
<tr>
<td>UPS PowerValue 11 RT 3 kVA S</td>
<td>$N/(9*2)$</td>
<td>$N/9$</td>
</tr>
<tr>
<td>UPS PowerValue 11RT 6 kVA</td>
<td>$N/5 – 1$</td>
<td>$N/5$</td>
</tr>
<tr>
<td>UPS PowerValue 11RT 10 kVA</td>
<td>$N/9 – 1$</td>
<td>$N/9$</td>
</tr>
</tbody>
</table>