RIELLO UPS: LIFESPAN OF UPS BATTERIES

INTRODUCTION

The battery system connected to an Uninterruptible Power Supply (UPS) is key to its continuous operation. Without a well-maintained, quality battery system that will perform when required, the UPS is practically useless.

For a UPS, battery failure is as serious – and unwanted – as any mains power outage. Batteries represent a significant share of the total cost of a UPS too. Good upkeep is essential.

Ignoring maintenance and/or service recommendations and letting the battery system fall into a poor state increases the risk to both the critical load and business continuity.

Although alternatives such as lithium-ion are becoming more popular and commercially viable, the majority of UPS today still use traditional sealed lead-acid batteries.

These cells have low energy-to-weight and energytovolume ratios – they are big and heavy – but they do provide high surge currents, so are ideal to provide backup during a mains failure or start up a generator.

UPS batteries tend to have either a 5 or 10-year design life. Yet performance begins to deteriorate from the moment dioxide paste is applied to its lead grids in the factory.

Due to their complex nature, each battery string and cell behaves slightly differently and has a unique rate of deterioration, which is influenced by a variety of external factors.

BATTERY DESIGN LIFE VERSUS SERVICE LIFE

Even though battery manufacturers will state their battery has a design life of 5 or 10 years, under EUROBAT (Association of European Automotive and Industrial Battery Manufacturers) international guidelines a battery is considered at the end of its service life when its capacity falls below 80% of its original.

In effect, this means that a 10-year design life battery will last for 10 years – assuming perfect operating conditions – but its performance will significantly reduce over time to a degree where it isn't safe to use in a UPS system.
Of course, no installation is ever perfect – this would be technically impractical, not to mention cost-prohibitive. Actual battery service life depends on several factors, including operational and storage temperatures, discharge levels, and how many times they are called into action.

Excluding these external influences, the operational capacity of a 10-year design life battery will drop below the required 100% capacity at year 6 (Figure 1). Over the remaining 4 years, the capacity will reduce to 80%, while the autonomy of the UPS will reduce too.

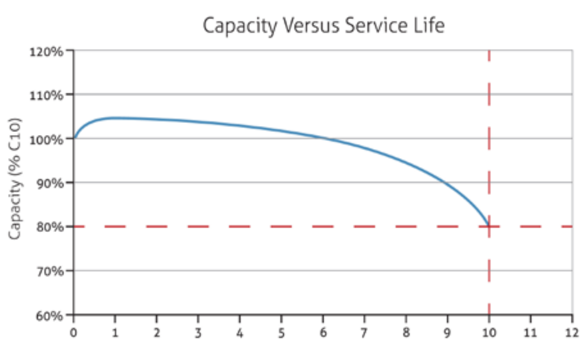

Figure 1

This helps explain why it's become accepted best practice to replace 10-year design life batteries in years 7 or 8.

This takes into account all the external factors that can reduce battery life and provides a safe enough margin for potential failure, without compromising the risk to the protected load. Comparable drop-offs in performance over time are also seen in 5-year design life batteries, which are typically replaced in either year 3 or 4.

PREMATURE BATTERY FAILURE THE BATHTUB CURVE

UPS batteries are no different to any other device or component and are subject to the bathtub curve mode of failure (Figure 2):

- **Period A – 'Infant Mortality' failures**: corresponds to early failures caused by a component or manufacturing defect or transportation problem.
- **Period B – 'Random' failures**: during the normal working life of a UPS the rate of these failures is normally low and fairly constant.
- **Period C – 'Wear Out' failures**: towards the end of working life, system failure rates increase significantly. Battery problems are common and can account for over 98% of UPS failures at this stage.

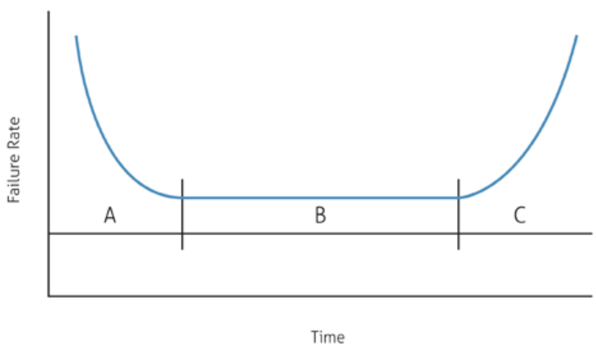

Figure 2

FACTORS AFFECTING THE LENGTH OF BATTERY LIFE

Temperature

High ambient temperature is generally considered to be the most common cause of premature battery failure. The higher the temperature, the quicker the chemical reaction, which increases water loss and corrosion.
Sealed lead-acid batteries have a rated capacity based on an optimum operating temperature of 20- 25°C. It is generally accepted that expected service life will reduce by 50% for every 10°C constant increase above the recommended temperature.

Short-term fluctuations in temperature have little effect on battery life.
Adjusting the float voltage depending on the temperature can reduce the effect of higher temperatures, but only marginally.

Figure 3 below shows the typical effects of the ambient temperature on the life expectancy of the battery.

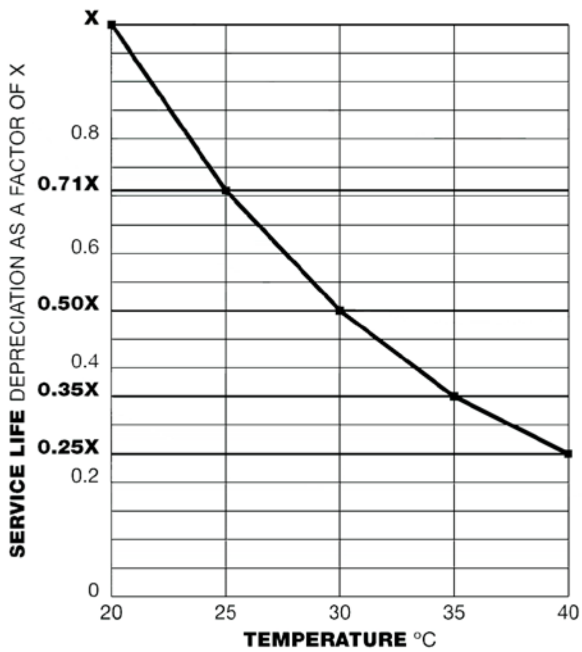

Figure 3 (From EUROBAT)

Frequency and depth of discharge

After a UPS runs on battery during a power failure, it recharges so it's ready for use again – this is known as a discharge/charge cycle.

Every battery is designed with a finite number of discharge and recharge cycles. Each discharge and subsequent recharge slightly reduces the capacity of the battery, in proportion to the depth of discharge – a battery that is only partially discharged can sustain more cycles than one that is fully discharged every time.

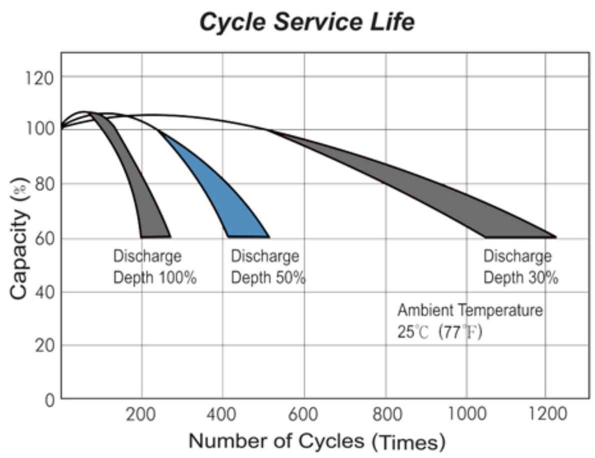

Figure 4

Operational voltages

Every battery manufacturer states the appropriate charging voltage rates for their specific cell designs. Charging outside of these recommended parameters can cause significant damage and reduce expected service life.

Overcharging can lead to excessive hydrogen and oxygen gases. This can cause internal dry out or in extreme cases thermal runaway, which can result in failure or even fire and explosion.

Undercharging or too low voltage can cause sulphate crystals to form on the plates, which over time will harden and reduce the battery capacity.

Ripple current

AC ripple generated by the rectifier, charger, or inverter is one of the biggest causes of overheating, which speeds up the deterioration of battery poles and will lead to premature failure.

Poor storage of unused batteries

Even if UPS batteries sit unused, their lifespan begins to decrease as they automatically discharge small amounts of energy.

If batteries need to be stored for a sustained period, it's advisable to top-up charge them according to the manufacturer's guidelines. Storing unused batteries at a temperature of 10°C or below will also help prolong their life.

Period of time batteries are left in a discharged state

If the battery is fully discharged to 0%, it is vital not to leave it in this state for any prolonged period as it can result in lasting damage. It is one of the main causes of sulphation (see below), which inhibits recharging and normal battery operation.

Incorrect battery application

Because of their specific role, UPS batteries are designed to deliver high rates of energy for a short time – generally a few minutes, although this can be stretched in certain applications.

There are other batteries, for example to back up telecoms or switchgear, that are designed to provide several hours' autonomy.
Using a battery designed for telecoms in a UPS system won't perform as well as one manufactured specifically for such an application.

The UPS topology itself can also impact on battery performance. Uninterruptible power supplies run in battery mode in two scenarios: firstly, if the mains power goes off; secondly, if the mains power input goes out of tolerance (i.e. voltage is too high/low or there is a frequency anomaly when running off a generator).

Some UPS topologies – online UPS – can handle wider input voltage and/or frequency windows, which means that the UPS will only run off the batteries in the case of emergency. This prolongs battery life.

If any of the problems highlighted above aren't promptly detected and resolved, it could kick-start a 'domino effect' that speeds up the failure of other batteries within the same system, even if they're in perfectly good condition.

For example, if one battery is overheating, it's likely to heat the surrounding cells, which could eventually cause them to fail too. Similarly, if a battery's impedance becomes a problem, the voltage applied to all the other cells within the system may need to increase, speeding up their rate of failure.

THE MOST COMMON PROBLEMS THAT IMPACT BATTERY LIFE

Grid corrosion

This occurs with a battery that has been in service for longer than its expected lifespan. Over time, the normal chemical reactions within the battery cause corrosion, for example shedding lead from the plates.

While these reactions can be slowed down, they cannot be stopped. Because of the compact design of most modern batteries, grid corrosion can often lead to short circuits.

Making a VRLA battery

Valve Regulated Lead-Acid (VRLA) batteries – also known as Sealed Lead-Acid (SLA) or Maintenance- Free – are the most commonly used with UPS installations.

A VRLA battery is made up of cells consisting of lead alloy plates immersed in an electrolyte of dilute sulphuric acid. This liquid (or gel) fills the space between the positive and negative plates, forming a closed circuit of cells. The chemical reaction creates DC current, which can be stored for later discharge.

VRLA batteries incorporate a valve that opens and relieves the pressure if an excess of hydrogen gas builds up inside the block. VRLA battery cases tend to be manufactured from flame retardant polypropylene or Acrylonitrile Butadiene Styrene (ABS) plastic.

Sulphation

A common condition in stop-start battery applications, as is the case with a UPS. It occurs when the battery does not receive a complete charge and leads to lead sulphate crystals forming within the electrolyte and at the plate terminals.

Sulphation reduces the battery's ability to receive a charge and increases internal resistance, leading to a longer charging cycle.

If the degree of sulphation isn't too high, batteries can be recovered by charging them at a higher current for approximately 12 hours. However, this higher charging current will generate extra heat. If the battery doesn't recover, replace and remove it.

Short circuits

The main cause of this is when paste on the positive electrode becomes porous, producing a loss of contact between the positive and the grid. During discharge, the plates can shed paste – if this material comes into contact with the battery plates, the cell will short circuit.

Dry out

Also known as water loss, this is caused when overcharging increases the concentration of acid in the electrolyte. As the battery gases, it loses water, which will lead to a decline in capacity over time. Dry out will eventually cause separator failure. A knock-on effect of dry out is an increase in selfdischarge and sulphation rates.

Thermal runaway

A condition accelerated by an increase in battery temperature which, in turn, releases energy that causes a further rise in temperature.

In essence, when the temperature inside the battery is so high that it cannot escape through the safety vents of sealed cells. This causes an increase in temperature around the exterior of the battery, which consequently raises the temperature within the battery again.
Ultimately, thermal runaway can result in case meltdown and expose the battery grid.

Top mossing

This tends to be a result of sloppiness and inaccuracy during the initial battery design and manufacturing process. For example, if separators and plates are badly aligned, the plate areas become exposed.
This makes it possible for a crystalline moss to form, which can lead to the cell self-discharging and result in a soft short failure. batteries it can do so, although they will only have 20% of their full capacity.

HOW TO PREVENT PREMATURE BATTERY FAILURE

Several steps can help maximise the service life of a UPS battery and minimise the risk of premature failure.

Importance of battery maintenance, monitoring, and testing

A proactive and rigorous preventive maintenance regime is recommended for the UPS system as a whole, but it is particularly important for batteries.

This strategy should start with a proper monitoring regime that detects any issues early enough to enable swift replacement, so they aren't allowed to develop into a full-scale failure. It is essential to monitor batteries at the individual cell level annually.

Physical tests should cover the inspection of terminals and connections for corrosion and checking batteries for any cracks, leaks, or swelling. Engineers should also tighten inter-cell connections, where necessary, clean the batteries, and remove any debris.

As well as these basic manual checks, dedicated battery monitoring systems can offer more advanced support. Ensure the monitoring system covers all the parameters recommended by the globally-recognised IEEE 1491 standard, including:

- String and cell float voltages
- String and cell charge/discharge voltages
- AC ripple voltage
- AC ripple current
- String charge current
- String discharge current
- Ambient and cell temperatures
- Cell internal resistance
- Cycles

Along with robust maintenance and monitoring, several tests can determine whether a battery is approaching the end of its life.

Many modern UPS will test their batteries regularly, usually every 24 hours, and will alarm if there are any faults. The test places a load onto the battery set and monitors the discharge. However, this only provides a general indication of the overall battery set, not the individual cells.

Impedance testing is a non-intrusive way of building up a 'history' of every battery cell. It should be undertaken annually to track performance over time, making it easier to identify any signs of weakness or deterioration.

An AC current is applied to each battery via probes attached to the block terminals, with the impedance measured and recorded in milliohms. This gives a broad indication of the general condition without placing any undue stress on the batteries or requiring them to be taken offline.

Discharge testing (also known as **load bank testing**) is the only examination that will truly determine the actual capacity of the battery string. It tests the batteries under normal and peak load conditions, showing which cells are holding the charge and which might be approaching their end of working life.

IEEE best practice recommends performing this at the time of installation, then ideally repeating the test every year. The main drawback with discharge testing is that the batteries must be taken out of service.

The worst-case scenario is that this can last for several days, although usually the batteries are available within 24 hours.

As the name implies, partial discharge testing offers something of a middle-ground. This involves discharging the batteries by up to 80%.

This reduces their availability, but they should be available again within 8 hours. If there's an emergency and the UPS needs to operate off batteries it can do so, although they will only have 20% of their full capacity.

Maintaining optimum operating temperatures and conditions
Most UPS systems are designed to operate safely at temperatures between 0-40°C, but as highlighted earlier, the higher end of this scale is problematic for batteries.

This leaves two options. Firstly, if the batteries are either internal to the UPS or stored in the same room, then keeping a constant temperature between 20-25°C will prolong battery life.

The alternative is to house the batteries in a dedicated, air-conditioned and humiditycontrolled battery room which is kept at the optimum temperature, while the UPS (and other IT equipment) are installed in a separate space.

Don't pack battery blocks too tightly together – leave sufficient room for case expansion and heat dissipation. This is particularly important to avoid thermal runaway if a block goes to open circuit.

Ensuring correct use of the UPS
In developed societies like the UK, the vast majority of power cuts are only momentary, lasting for seconds or at worst a few minutes. If you are the exception to this rule and experience prolonged power outages, it is advisable to not let your battery completely drain to 0%.

Where possible, switch off the equipment or transfer to another backup source such as a generator, then power down the UPS to ensure the batteries don't fully discharge.
As covered earlier, batteries can only go through a finite number of charge-discharge cycles and if you don't fully discharge, you'll get more cycles.

Most modern UPS also incorporate a **Battery Care System** that is designed to extend the working life of the battery set and optimise its performance.

These systems automatically test the batteries at regular intervals and protect against slow discharges and ripple currents.

Battery Care Systems also offer users a range of recharge methods including:

- **Floating**: the charge state of the battery is continuously monitored. When the mains power supply is present, the batteries are charged at a pre-set voltage level and limited current relative to the recharge time required and the capacity of the battery itself.

- **Two-level**: this recharge is at limited current with two levels of voltage. In the first instance, the process uses a quick charge voltage, whilst in the second stage a float charge. This type of charging is mainly used with open-vented batteries or other types when an accelerated recharge time is required.

- **Cyclical**: this recharge is sometimes recommended by battery manufacturers to prolong the battery life.

- **Commissioning**: this charge method is useful every time new batteries are installed in the UPS. The voltage is increased to 2.4 V./element for a maximum of 24 hours. This ensures perfect equalisation of the battery charge, guaranteeing uniform discharge and wear of the battery monoblocks.

CONCLUSION
A battery system in a UPS can consist of a single battery or extend to thousands of cells. Unfortunately, accurately measuring the condition and predicting the failure of batteries isn't an exact science, with so many variables influencing the rate of deterioration. Always keep in mind the safety margins (i.e. replacing 10-year design life batteries in year 7-8), along with robust battery monitoring and maintenance regimes. Gambling with battery performance is the equivalent of waiting for them to inevitably fail, an unacceptable approach within any missioncritical environment.

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