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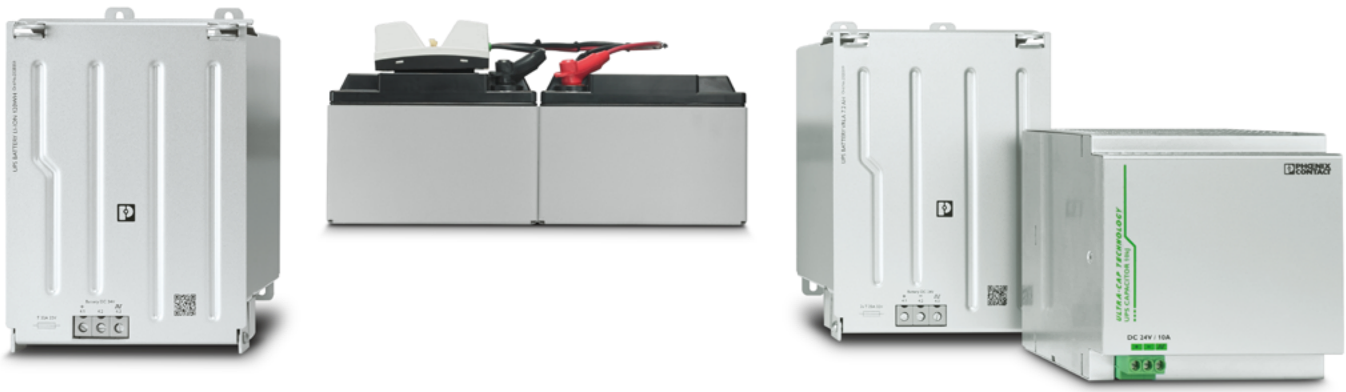

Energy storage and monitoring to maximize UPS uptime

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Introduction

An uninterruptible power supply (UPS) is a great way to ensure that power to important loads is not lost in the case of a power failure. When incoming power to the UPS is lost, it immediately switches into battery mode, which allows the connected loads to run off this reserve energy. But if the UPS itself fails, then any power loss will shut down the entire system. Therefore, it is important to make sure a UPS is reliable and reaches its full lifetime potential. Using the proper battery for each application and constantly monitoring the system to maximize uptime can ensure the full life of a UPS.

INSIDE:

Batteries

No matter how good a UPS is, without a battery, it can do nothing to buffer power. If the UPS loses incoming power and the battery is discharged, disconnected, or dead, then the entire system will shut down. It is therefore crucial to use the proper battery for each application. There are many types of battery technologies, but two popular options are valve-regulated lead-acid (VRLA) and lithium-ion (Li-ion). This section will explore the basic technologies of VRLA and Li-ion batteries, as well as the advantages and disadvantages of both.

Valve-Regulated Lead-Acid (VRLA)

Valve-regulated lead-acid batteries are a variant of lead-acid batteries, which are commonly used in automotive. Simply put, they operate by suspending two plates of lead (the electrodes) in diluted sulfuric acid (the electrolyte). This enables the flow of electrons when a chemical reaction occurs between the lead and sulfuric acid. This reaction produces lead sulfate and water, and charging the battery reverses this reaction. Charging can also produce hydrogen and oxygen through hydrolysis if the charging current is too great. In a typical lead-acid battery, these gases escape and must be replenished with water or electrolyte. Compare that

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to a valve-regulated battery, where the gas is retained and recombined into water (usually with the help of a catalyst). If the pressure ever gets too high, the safety valves open and allow the pressure to return to safe levels.

Lithium-ion (Li-ion)

Lithium-ion batteries are similar in concept to lead-acid batteries, except they use different materials. The electrodes, in this case, are typically a metal-oxide for the cathode (positive side) and graphite for the anode (negative side). This metal oxide is usually lithium-cobalt oxide, lithium-iron phosphate, or lithium-manganese oxide. The electrolyte is typically a mixture of organic carbonates.

To create power, lithium ions carry current across the battery from the negative to the positive electrode. When a current is applied, this process is reversed, and the ions travel back to the negative electrode. Lithium batteries can catch fire if they are overcharged or short-circuited, so various safety devices are installed such as voltage regulators, temperature sensors, and microcontrollers. Many batteries and UPS systems will disable themselves if unsafe conditions are reached. The type of metal oxide used on the cathode can affect the safety of the battery. Therefore, the Federal Aviation Administration (FAA) regulates the use of lithium batteries when flying, to be cautious.

Comparison of different factors

Cost: Lead-acid and VRLA batteries, in general, are among the most cost-effective batteries on the market. Compared to Li-ion batteries, which are often multiple times more expensive, they have the lowest purchase price. However, the purchase price is not the only factor when it comes to batteries.

All batteries reach end of life, and when they do, they must be replaced. In general, Li-ion batteries will last longer, and therefore, need to be replaced less often. This can result in lithium-ion saving money over the system's life, which could justify the increased purchase price. But based on initial cost alone, VRLA is the better option.

Size and weight: In the same space, Li-ion batteries can hold more energy than a VRLA. This means Li-ion batteries are more energy-dense and are useful when space is limited in a system. This size savings extends to weight as well. Their lighter weight makes Li-ion batteries suitable for use in mobile phones, tablets, and computers.

Depth of discharge: A VLRA battery should never be discharged to lower than 50% of its total capacity. This is referred to as the battery's depth of discharge. A Li-ion battery can be discharged down to 15% of its total capacity. This means Li-ion batteries also have a higher effective capacity and can sustain a load for a longer duration when compared to VLRA.

Charging cycles: A battery has a maximum number of charging cycles before it starts to degrade and lose capacity. The number varies based on the environment the battery is operating in, as well as the depth of each discharge. In general, a VRLA battery provides 200 to 300 cycles, while a Li-ion battery provides 500 to 1,500. If used in a system that is constantly discharging, Li-ion batteries will need to be replaced less often than VRLA.

Shelf life and discharge rate: Batteries that are not connected to power will naturally discharge over time. If left without power for too long, the battery could discharge to a point where it can no longer be recharged. This point where the battery cannot be recharged is related to depth of discharge, which was discussed earlier.

A VRLA battery should be stored at room temperature (around 20°C) at 100% capacity. It should be checked periodically and recharged every six to twelve months, based on the size of the battery. If not recharged, it will discharge below the recommended 50% and lose capacity. Lithium-ion batteries should also be stored at room temperature, but only at a partial charge (around 40-50%). They should be checked and recharged every 16 to 24 months if not connected to power.

Temperature: In general, batteries are very susceptible to the temperature at which they operate. Batteries stored at too high of a temperature will discharge faster and have a lower total lifetime. Batteries stored at too low of a temperature will lose performance and can be damaged if charged. The optimal temperature for all batteries is approximately 20°C (68°F), but the type of battery affects the range that it will operate in. The typical range for a VRLA is 0°C to 40°C, while a lithium-ion ranges from -20°C to 60°C.

Environmental impact: Batteries can pose a significant environmental risk if not properly disposed of and recycled. Lead-acid batteries especially are a risk, as the toxic lead can seep into the ground and reach water supplies. Compare that to lithium-ion, where the waste is mostly harmless.

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This may make it seem like lead-acid is the more harmful of the two, but that is not necessarily the case. Almost all lead-acid batteries are recycled because the process is simple and cost-effective. The lithium-ion recycling process is not profitable and therefore occurs much less often. Combine that with the increased number of lithium-ion batteries used in consumer electronics, and there is a case to be made that they are the more harmful type of battery.

All that being said, an improperly disposed of VRLA battery will be much more toxic to the environment than a Li-ion battery. On the scale of using batteries just for a UPS system, the Li-ion battery's longer lifetime means that fewer of these batteries would be thrown away. Any user could also make a concerted effort to recycle Li-ion batteries and reduce their impact.

Summary

It may seem from these comparisons that Li-ion batteries are the clear choice, and in many ways, they are. The superior size, weight, charge cycles, and operating temperature make them a great choice for any application.

That being said, there are still cases for VRLA. Besides the upfront cost savings, there may be no noticeable difference between the batteries given the right application. In cases where the batteries are in an ideal environment, being properly charged by the UPS, and not discharging too often or deeply, VRLA batteries could function identically to lithium-ion. The lifespan of the VLRA will still be shorter, but could still be long enough that its replacement costs are less than that of the lithium-ion. Table 1 gives a breakdown of various factors and how VLRA compares to lithium-ion.

Table 1

Battery type	Cost	Size and weight	Depth of discharge	Charging cycles	Shelf life	Temperature
VRLA	Lower	Heavier	Lower	200 – 300	6 – 12 months	0°C – 40°C
Lithium Ion	Higher	Lighter	Higher	500 – 1500	12 – 24 months	-20°C – 60°C

Capacitors

Capacitor modules (also called buffer modules) are another option for energy storage if batteries do not fit the application. Instead of using battery cells to store energy, the modules use capacitors. Capacitors are constructed with two metal plates separated by a dielectric. When a voltage is applied, an electric field forms across the two plates. The field collects positive charges on one plate and negative charges on the other. When the voltage is removed, the capacitor is discharged and provides energy to the circuit. When enough capacitors are connected in parallel, they can act as a back-up source for systems.

The main advantages of these capacitor-based modules are wider temperature range, longer service life, more charging cycles, and little to no maintenance. However, this all comes at the expense of capacity and back-up time. These types of modules are meant to back up small loads, less than 5 Amps for around one to five minutes. This makes them great for safely shutting down low-power components or protecting against the occasional power blip, but not for backing up large systems for extended power outages.

Monitoring

Even the best battery will eventually reach end of life, so finding the optimal time to replace it can save system downtime and money. With system monitoring, the user can obtain data on the availability of each battery. This data can also be used to find existing problems in the system that may be prematurely killing batteries. This section will review three levels of system monitoring and the advantages of each.

No monitoring: In an installation with 100 batteries, every battery is going to degrade slightly differently. The easiest way to deal with this is by replacing every battery after some predefined period. The advantage is that the maintenance is easy to schedule, and there is no system downtime (excluding a faulty battery). The downside is the cost of replacing batteries that potentially could have continued to operate for much longer.

Simple monitoring: The simplest way to monitor would be an indication on the UPS that the battery has not or will not support the load. This could be accomplished with local or remote indication, and it ensures that only bad batteries will be replaced. The advantage of this approach is that there are no wasted replacements. The disadvantages are increased complexities in maintenance, because failures can be random, as well as the need for some way to constantly monitor all the systems.

Advanced monitoring: The most advanced form of monitoring analyzes many different factors of a battery and provides data based on those factors. For example, Phoenix Contact's IQ Technology analyzes batteries and reports data such as remaining charge, remaining lifetime, current temperature, output voltage, and much more. This sort

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of data allows the use of preventive maintenance. Battery replacements can be scheduled for a specific period and, using data from the UPS, only the batteries near their end of life will be replaced. The main disadvantages are setting up a system to collect all this data and training users on how to use any associated software.

Conclusion

To ensure the availability of a UPS system, proper consideration must be taken of each application and its requirements. When there is a power failure, the proper battery will make sure the system does not go down, and everything runs smoothly. In conjunction with a good monitoring system, maintenance can be regularly performed, so there are no unexpected failures. Combined, these two factors will maximize uptime and ensure that there is backup in the case of a power failure.

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