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Straight talk about capacitors in your UPS

What they are, what they do, why they're essential in your UPS — and the importance of proactive maintenance for these humble and often overlooked components.

Executive summary

Capacitors are fairly simple devices, ranging in size from a thimble to a soda can, that smooth out fluctuations in electrical voltage. A typical UPS contains a dozen or more different types and sizes of capacitors — small ones that smooth out the power supplied to the UPS processor (its on-board intelligence), and large ones to regulate the power that flows to protected equipment.

Like batteries, capacitors degrade over time. A typical capacitor might be rated by the manufacturer for, say, seven years of round-the-clock use, but could potentially deliver up to 10 years of useful life under favorable operating conditions.

When a capacitor fails, you might not see any visible effects, but other capacitors will have to take over the workload, which will shorten their useful lives. In many cases, a capacitor failure triggers the UPS to switch to bypass mode, during which it can't protect downstream loads.

To maximize the performance and reliability of your UPS, treat capacitors as the perishable commodity they are, and plan on replacing them at or near the end of their rated service life. Eaton® customer service engineers can diagnose the condition of the capacitors in UPSs and perform a full or partial replacement of capacitor banks, if necessary, to maintain UPS performance up to factory specifications.

Proactive attention to this often-overlooked element of UPS architecture — the humble capacitor — can extend the value of the UPS system that protects your critical electronic systems.

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1. What is a capacitor?

A capacitor is a fairly simple electrical device that stores and releases electrical energy. These devices can be as small as your thumbnail or as large as a soda can — depending on the amount of voltage they're expected to digest (their rated capacity). Generally encased in aluminum or chromium-plated cylinders, capacitors contain a pair of conducting surfaces (often metallic plates or electrodes) which are separated and insulated by a third element, called the dielectric medium.

Why is this important? Along with the surface area of the aluminum plate, the thinness of the dielectric layer determines overall capacitance — that is, how much charge can be stored or managed by the capacitor. The ultra-thin oxide layer possesses remarkable insulating characteristics, making it possible to manufacture very small capacitors that handle very high workloads.

2. What do AC and DC capacitors do?

The primary use for DC capacitors in UPS applications is to smooth out fluctuations in voltage — a process also known as “supply voltage filtering.” If there's a change in voltage input, the capacitor dampens the voltage change, eliminating the peaks and filling in the valleys to help maintain a constant voltage level.

AC capacitors have much of the same characteristics as DC capacitors in that they have an expected period of useful service and should be considered as perishable commodities. AC capacitors are found primarily in the input and output filters sections of the UPS. They smooth out input transients and reduce the harmonic distortion on the utility input to the UPS and more importantly they are connected directly to the critical load output and help in controlling the waveform shape of the UPS output voltage.

3. How many capacitors are in a typical UPS?

The inventory of capacitors inside a UPS varies tremendously depending on the magnitude of the job to be done, that is, the kVA rating of the unit. To put this in perspective, a typical personal computer contains about 50 capacitors; a 750 kVA three-phase UPS may have hundreds of them. Even the smallest UPSs use dozens of capacitors.

4. Do manufacturers use a proprietary capacitor design?

No. Capacitors are manufactured by a variety of vendors in accordance with industry standards. Chances are, no matter where you bought your UPS, it contains capacitors that have been sourced from one of the same major national or global vendors.

5. Do capacitors degrade over time under normal use?

Yes they do, just as batteries do, and for similar reasons. Wet capacitors, when properly designed and fabricated, show very gradual changes in essential characteristics over time, when operated at normal rated voltages. However, the paper, aluminum foil, and electrolyte inside the capacitor are subject to normal breakdown. As those materials age and start to degrade physically and chemically, they lose capacitance. Ultimately, the capacitor no longer performs its job.

Adverse operating conditions such as excessive current and heat can hasten the demise of capacitors.



Figure 1. Capacitors with clear visual evidence of failure. Note, capacitors may fail with no obvious signs.

6. How long do capacitors usually last?

The theoretical operational lifetime of a capacitor is a mathematical function of the rated voltage, applied voltage, current through the capacitor, ambient temperature and thermal resistance. In practice, you can estimate expected service life based on the manufacturer's rated lifespan and the operating temperature of the device. The hotter the operating temperature, the shorter the life.

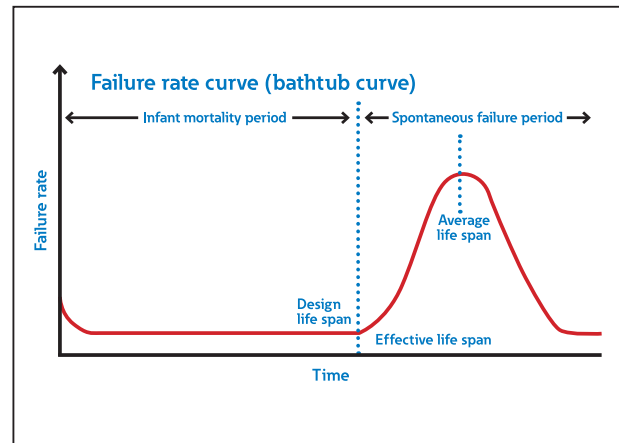


Figure 2. Curve showing design life span and average life span.

Design life span – A targeted life span specified at the design stage.

Effective life span – The period of time where the capacitor has gone beyond the infant mortality stage and has entered the Spontaneous failure period. At this stage, the number of failures is less than the specified values.

Average life span – The average life span of capacitors in a UPS application, at a specified temperature.

Failures are certainly possible any time after the manufacturer's rated service life, and failures increase in likelihood as the capacitors get older.

Based on the manufacturer's rated service life, it is recommended to schedule a full replacement of capacitors used in the primary power-train portion of the UPS around 7 years of operation. However, newer UPSs typically have oil filled DC capacitors that are rated for the full life of the UPS.

When a capacitor fails, you might not see any visible effects, but other capacitors will have to take over the workload, which will, in turn, shorten their remaining lives. In many cases, a capacitor failure triggers the UPS to switch to bypass mode, during which it can't protect downstream loads.

Capacitor type	Rated service life
DC (electrolytic)	Life of UPS
DC (oil filled)	7 years
AC (oil filled)	7 years

Figure 3. Estimated capacitor service life for both AC and DC capacitors.

7. What conditions influence capacitor longevity?

As lifespan is a function of rated voltage and operating temperature, it logically follows that you can shorten the useful life of a capacitor by overstepping its design thresholds in either of those areas. For example:

- **Excessive current** – Capacitors can be destroyed if they are regularly exposed to over-current conditions, such as steady current that exceeds the manufacturer’s rating. Short periods of excessive ripple current are relatively harmless, as long as the capacitor doesn’t have to overheat to compensate.
- **Over-work** – Capacitors fail more frequently if they have to filter an unusual amount of voltage noise or frequent transients (sharp, brief disruptions in the sine wave.) Much like an air filter that operates in a dirty environment, the harder it has to work, the sooner it will have to be replaced.
- **Excess heat** – Whether from inside the capacitor (for instance, caused by lack of airflow due to a clogged air filter) or from outside (due to ambient temperature), excess heat will eventually start to evaporate the solution inside the capacitor and build up unsafe pressure that can cause failures.

Take, for example, a capacitor that has a theoretical life of 32 years at 405 V and 20 degrees Celsius. If you increase its workload to 540 V and twice as much heat, the capacitor will probably last only about eight years — a significant compromise.

The good news is that good management — operating the UPS within its rated capacity in a clean, cool environment — can mitigate these risk factors.

8. What actually happens to the capacitor when it fails?

A capacitor can fail in an “open” condition — simply stop doing the work for which it was intended. This kind of failure is quiet and can pass unnoticed. Or a capacitor can fail in a “short” condition – developing a leak of the dielectric medium or even venting with a loud pop that sounds like a firecracker.

The electrolyte is conductive, naturally, so spilled electrolyte can make unintended connections that could possibly disrupt UPS performance. The electrolyte is also corrosive and could interact with other components inside the equipment. For these reasons, many electrolytic capacitors have a scoring mark at one end, which is designed to rupture and leak gently, rather than allowing the container to vent suddenly and spread electrolyte across a wide area.

9. What happens to UPS functionality when a capacitor fails?

This depends on where the capacitor is located, the number of capacitors working in series (tandem) or parallel to perform an equivalent task and the overall health of the other capacitors. For instance, if capacitors are operating well below their voltage rating, one or two capacitors might readily be able to take over for a failed capacitor without significantly affecting UPS operation.

A failed capacitor in the power train can diminish the unit’s overall filtering ability, but it won’t render the unit nonfunctional. However, when a capacitor in the power train fails, a typical three-phase UPS transfers to bypass mode, whereby the power stream bypasses the UPS’s filtering electronics. During this time, the UPS — although operational — isn’t actually protecting downstream equipment.

In rare cases, a failed capacitor can disrupt power to the on-board computer (the logic processor), but leading UPSs are designed to execute a safe and orderly shutdown in that unlikely event. It’s never a good thing to have components shorting out inside your electronic equipment, whether or not that single component is mission-critical to the overall architecture.

10. If the UPS keeps working, why should I worry about replacing capacitors?

When an individual capacitor fails, it is often a sign that other capacitors are not doing their jobs either. You might see obvious evidence of one or two failed capacitors that have split or leaked, but visible inspection would not reveal other capacitors that have failed in an “open” condition and perhaps actually caused the other failures. Left unchecked, this condition could trigger the failure of still more capacitors and ultimately diminish UPS performance.

Capacitor replacement definitely falls into the category of preventative maintenance. By the time performance degradations show up on monitoring reports, the process has perpetuated itself, and the replacement cost will be higher than if end-of-life capacitors had been identified and replaced earlier.

11. Is there anything I can do to help extend the life of capacitors?

Probably the biggest factors under your control are to maintain the recommended ambient temperature, humidity, and cleanliness. Keep air filters clean, so air can flow freely to keep the unit cool. And when replacing capacitors on old equipment, don’t install capacitors that are below the voltage rating of the original parts.

Good data center management can be a powerful testament in prolonging equipment life. Complete power capacitor replacements are recommended to proactively insure the reliability of the UPS against a catastrophic failure and reduce the risk of unscheduled downtime.

Conclusion

To maximize the performance and reliability of your UPS, treat capacitors as the perishable commodity that they are, and plan on replacing them at or near the end of their rated service life.

Be wary of choosing a third-party service organization over a UPS manufacturer's certified technicians to replace capacitors. If the manufacturing company designs, engineers and manufactures your UPS, they will know it better than anyone else, and the technicians are specialists. Technicians should be trained, certified and will likely have access to proprietary diagnostic software and the latest engineering updates as well as complete access to to-level technical support (all documentation, engineering data and drawings, technical data and updates). You can be assured that only factory-authorized parts with appropriate specifications and the latest firmware or revisions will be installed in your UPS, not after-market parts of unknown quality or specs.

For example, only Eaton service technicians are authorized to work on Eaton UPSs, with the exception of a few models. More than 650 customer service engineers (200+ in the U.S. alone) stand ready to provide premium service for your three-phase UPS.

You can count on Eaton customer service engineers to perform this function for you—and to accurately determine which capacitors are problematic, whether individual capacitors or whole banks of capacitors should be replaced, and to provide replacement parts that meet factory specifications.

Proactive attention to this often overlooked element of UPS architecture — the humble capacitor — can extend your confidence in the UPS system you depend on to protect critical electronic systems.

About Eaton

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Eaton is a power management company with 2015 sales of \$20.9 billion. Eaton provides energy-efficient solutions that help our customers effectively manage electrical, hydraulic and mechanical power more efficiently, safely and sustainably. Eaton has approximately 97,000 employees and sells products to customers in more than 175 countries. For more information, visit www.eaton.com/powerquality.

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