Powering Business Worldwide

White Paper

Straight talk about electrolytic capacitors in your UPS

A white paper from Eaton Corporation

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

Electrolytic 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 electrolytic 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, electrolytic capacitors degrade over time. A typical capacitor might be rated by the manufacturer for, say, five years of round-the-clock use, and could potentially deliver up to 8 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 your 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 an electrolytic 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 electrolytic capacitors that handle very high workloads.

2. What do electrolytic capacitors do?

The primary use for electrolytic capacitors 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 or eliminates the voltage change to the output, eliminating the peaks and filling in the valleys to maintain a constant voltage level.

3. Where are electrolytic capacitors found in my UPS?

A dozen or more different types and sizes of electrolytic capacitors are present in a typical UPS. These capacitors all perform the same type of function—voltage regulation—but at different voltages and filtering levels.

For example, fairly small capacitors filter supply voltage required by the power supply that supports system electronics (the logic that controls UPS functions). Much larger capacitors are used in the power train to smooth out the voltage being delivered to protected loads. Those capacitors would be found after the rectifier(s) and on the DC link that connect the UPS to backup batteries.

Working as filtering elements, these capacitors are essential contributors to the overall purpose of the UPS, which is to take unpredictable or erratic supply voltage and turn it into a filtered, steady voltage.

4. How many electrolytic 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, 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.

5. Does Eaton 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.

6. Do capacitors ever wear out?

Yes they do, just as batteries do, and for similar reasons.

Wet electrolytic 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.

7. 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.

Engineers from our primary capacitor vendor tell us they expect their capacitors to deliver at least five years of round-the-clock service and seven years of shelf life. In our experience, their capacitors often last eight to 10 years. But, failures are certainly possible any time after the manufacturer's rated service life, and failures increase in likelihood as the capacitors get older.

8. 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 DC 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.

9. 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 pop that sounds like a small 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.

10. 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 our UPSs are designed to execute a safe and orderly shutdown in that unlikely event. Furthermore, a failed capacitor can trigger a chain reaction as other capacitors struggle to take over the workload.

11. Will the UPS itself be harmed if it has a degraded or failed capacitor?

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. As mentioned earlier, a capacitor that vents acidic liquid could possibly do secondary damage to other components.

However, in most cases, the effects are minor. For instance, if a capacitor fails in the logic power supply, it might damage the processor board, but that board would be replaced anyway to replace the capacitor. Even a bursting capacitor in the power train is more startling than damaging, because those capacitors are protected with fuses.

12. 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 "a stitch in time saves nine." 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.

13. When should capacitors be replaced?

Our recommendation is to replace capacitors after five years of service. Eaton recommends that wet capacitors be inspected for deformation, leaks, and other apparent problems during annual preventive maintenance—and that those within six months of their rated life be replaced. Replacing them a little early helps account for environmental and operational factors that may have shortened their lifespan.

You might be wondering why some UPS vendors say you won't have to replace capacitors in their UPSs, when they use "off the shelf" capacitors from the same sources. Usually, that claim is made when the rated service life of the entire UPS is about equivalent to the rated service life of the capacitors. This is generally true of smaller UPSs that don't have replaceable batteries. With those units, you would be swapping out the entire UPS due to battery failure before the capacitors reached the end of their service lives.

14. How will I know which capacitors need to be replaced?

If a capacitor is ruptured or leaking electrolytic fluid, that's a pretty good clue. But the determination often requires detective skills for several reasons:

- There's no automated notification. UPS monitoring software detects performance issues that may be caused by failed capacitors, but it can't tell you which capacitors are to blame.
- The dead capacitor might look just fine. When a capacitor fails in an "open" condition (quietly stops working), you'd never know by visual inspection. There will be no bulging, leaking, or visible degradation at all.
- There are so many of them. If you meter capacitance relative to the capacitor's intended rating, you can spot under-performers and failures, but there are hundreds of capacitors to test in a large UPS system.
- The blown ones might not be the culprits. As some capacitors begin to under-perform or fail, others will have to over-perform to compensate. As a result, the martyrs may leak, burst, or stop working—taking the blame, while the degraded "open" capacitors that started all the trouble remain undetected.

That's why Eaton technicians follow best practices based on four decades of experience in the field. Our experts know how to assess capacitor health and pinpoint which capacitors need to be replaced.

15. What is the recommended strategy for testing and replacing capacitors?

For capacitors in the system logic, you'd replace the logic board because it's an integrated unit. For capacitors in the power train, service technicians can replace the capacitors individually or all together.

The preferred strategy depends a lot on the age and size of the system. For instance, if your large UPS system is 10 to 15 years old, piecemeal replacement of capacitors might appear to be more cost-effective in the short run. However, ultimately, it's more costly and risky for the reasons stated earlier. If some capacitors are visibly failing, those failures may have been triggered by the failure of others. But, it can be difficult or time-consuming to determine which capacitors caused the initial failures.

Consider also that testing and replacing individual capacitors can take perhaps five or six hours for a large three-phase system. In contrast, a technician can replace an entire bank of capacitors in less than an hour. If the capacitor failure rate has been on the rise, you may soon find that one-by-one replacement has led to replacing most of the capacitors anyway—but at greater cost and inconvenience than wholesale replacement.

16. How can I determine if it's worth it to replace the capacitors in an older UPS?

The biggest factors are the age of the UPS and the rate at which capacitors are failing. As a UPS ages beyond the rated lifespan of the capacitors, you're likely to see more capacitor failures. If you're hearing that tell-tale "pop" about once a month, it might be time to swap out all the capacitors.

If your UPS is 12 to 15 years old, you might want to balance that investment with obsolescence issues unrelated to capacitors. Are you having trouble getting other spare parts? Does the vendor still support this unit? Some Eaton customers have systems that have been in service for 15 to 20 years, and we still support them.

17. Is there anything I can do to help extend the life of electrolytic 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 electrolytic capacitors on old equipment, don't install capacitors that are below the voltage rating of the original parts.

A major aerospace manufacturer has an Eaton UPS that is approaching 20 years in service. Operating in an immaculate environment under near-perfect operating conditions, this vintage UPS still looks and performs like brand new. That's powerful testament to the role of good data center management in prolonging equipment life.

18. My UPS is a very old model. Can it accept today's capacitors?

Wet electrolytic capacitors have been in commercial use since the 1890s—and although they have been continually improved with new materials in the last century, they haven't changed much in the last decade or two—the lifespan of a UPS.

Since the technology is relatively unchanged, even if one vendor has discontinued making a certain capacitor, Eaton can usually source it from another vendor, retaining the same physical dimensions, ratings, and connections. At worst, if there is no exact modern-day counterpart for a very old capacitor, you might have to change out a bank of capacitors—but if the unit is that old, it was probably time for wholesale replacement anyway.

Standards for capacitance values have changed slightly over the years. Instead of the old values such as 15 microfarads (MF), 32 MF, 50MF, etc., you'll find 16 MV, 33 MF, 67 MF, etc. However, if the replacement capacitor is close in value, that's okay, because tolerances are rather broad. In fact, capacitance value can be anywhere from 20 percent below or 100 percent above the value of the capacitor being replaced.

One advantage of modern components is that they are usually more compact, so if you cannot get a capacitor of exactly the same rating as the original, chances are you can get a higher-rated capacitor into the same space—and enjoy the advantages of cooler operation, longer capacitor life, and improved reliability.

19. Who actually replaces the capacitors? Can I use a third-party service provider?

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. Capacitor replacement is covered under our manufacturer's warranty (but not included in annual service contracts).

Check the credentials of third-party service organizations that claim to be authorized service providers or to have Eaton-certified personnel, parts, or diagnostic tools. In North America, Eaton has generally not authorized or certified third-party providers to service your Eaton UPS system. Except for certain government-owned systems, we do not typically provide third-party technicians with factory training, certifications or the authority to use our proprietary software diagnostic tools.

This strategy has some important advantages for you as an Eaton customer:

- We designed, engineered and manufactured your UPS (brand names include Powerware, Exide Electronics, Best Power, IPM and Deltec). That means we know it better than anyone else, and our technicians are specialists.
- Eaton technicians 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).
- Eaton technicians receive ongoing factory training and current certification. At any time, you can request documentation from us to verify the training and certification of the customer support engineers in your area.
- 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.

20. 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.

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.

To find our more about Eaton products, services, and support, visit us on the Web at www.eaton.com/powerquality.