Powerware

White Paper

The Benefits of a Preventive Maintenance Service Plan for your UPS

A White Paper from Eaton Corporation

Executive summary

Eaton® Corporation, a global leader in power quality, distribution and control, strongly endorses a preventive maintenance service plan to maximize the reliability of an Uninterruptible Power System (UPS). Because companies rely on a UPS to deliver continuous power without any disruption to their business, a maintenance plan is a critical component to ensuring that a UPS minimizes the risks of downtime and performs as expected.

To validate the importance of a preventive maintenance service plan in enhancing overall UPS reliability, as well as to help end users understand the prevalence and consequences of downtime, Eaton analyzed data collected from our service organization, in addition to numerous findings on downtime compiled by industry experts. This research confirms that routine preventive maintenance significantly increases UPS reliability.

This white paper examines the various threats that can lead to a UPS failure and addresses the specific ways in which a preventive maintenance service plan can dramatically minimize those risks.

Introduction

Implementing a preventive maintenance service plan for your UPS is much like completing routine repairs and inspections on your vehicle. Not only is completing scheduled maintenance recommended by every auto manufacturer, but the findings can help detect a wide range of ailments under the hood *before* they become serious issues. In the same way that analyzing pressure and fluid levels, checking the alignment and inspecting the brake pads at specified mileage intervals can maintain performance and factory specifications for your vehicle, preventive maintenance helps ensure the ongoing integrity of your UPS. After all, it's much more palatable to tweak the alignment at the first sign of needed adjustment, as opposed to finding out down the road that you now need four new tires—not to mention, the original alignment that likely would have preserved the tires in the first place.

A variety of different UPS service options are available, including routine scheduled maintenance, emergency parts and labor service, and other value-added offerings such as remote monitoring capabilities. Regardless of the exact course of action you choose, an effective preventive maintenance plan will save time and money by minimizing business interruption and the costs of downtime, as well as enhancing your overall return on investment by extending the lifespan of your critical power equipment. Preventive maintenance is also crucial to achieving maximum performance from your equipment by affording the opportunity to detect and repair potential problems before they become significant and costly issues, thereby minimizing the risk of unplanned downtime.

Downtime is disastrous

No matter how you assess it, downtime carries an enormous price tag. Electric Power Research Institute (EPRI) estimates the national cost of power interruptions at approximately $80 billion per year to U.S. electrical customers, with momentary interruptions accounting for two-thirds of the total cost at $52 billion.

The U.S. economy loses between $104 billion and $164 billion to outages each year, and another $15 billion to $24 billion to power quality issues, according to EPRI. Furthermore, the annual downtime average for the utility grid in the U.S. is currently eight hours and 45 minutes. However, with on-site generation equipment and UPS solutions, this downtime can be reduced to the equivalent of five minutes and 15 seconds per year.

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Other studies concur that the cost of network downtime can be crippling to a corporation, with financial implications starting at about $10,000 an hour for smaller companies and extending to $1 million per hour and upwards for those who rely heavily on measures such as e-commerce.

What are the root causes of downtime?

It may come as a surprise that more than two-thirds of downtime events stem from preventable causes, according to the 2007 Study of Root Causes of Load Losses compiled by Eaton. Studies have also shown that approximately 4 percent of UPS failures are the result of components wearing out due to age, while up to 20 percent fail due to bad batteries. Studies into the causes of downtime reveal that:

Preventable downtime (67%) is caused by:

- Human error
- Lack of process
- Incorrect procedures
- Poor design
- Inadequate redundancy
- Insufficient maintenance

Non-preventable downtime (33%) is caused by:

- Equipment failure (despite proper maintenance and testing)
- Supply chain/service chain failure
- Cyber terrorism

Example of UPS load losses by root cause[1]

Of the 67 percent of reported load losses identified by Eaton during analysis of its own service data on Powerware UPS products, failures resulting from preventable human error and site design problems were attributed to:

- Site operations error
- Site design error
- Service technician error
- Batteries
- Product design
- Defective parts
- End of life/product wear out
- Factory quality

The positive news is that routine preventive maintenance appreciably reduces the likelihood that a UPS will succumb to downtime. In fact, the same load loss report revealed that customers without preventive maintenance visits were almost four times more likely to experience a UPS failure than those who complete the recommended two preventive maintenance visits per year. These findings validate the significance of regular UPS service as a highly effective means to reduce the potentially devastating effects of downtime.

The most common causes of UPS failures

There are numerous reasons why a UPS fails. The most common causes are:

1. **Batteries.** The heart of any UPS, batteries require inspection and maintenance regardless of their age or warranty status. Studies show that up to 20 percent of UPS failures can be attributed to bad batteries, with temperature and cumulative discharges cited as the primary culprits. During a preventive maintenance visit, data is obtained from thorough testing procedures, during which impedance or conductance measurements trace the battery performance and identify any batteries with internal potential failures.

[1] Eaton Corporation 2007 Powerware UPS Load Loss Report

2. **Fans.** Some fans fail because of their own electrical or mechanical limitations, or when their ball bearings become dried out. Fans may perform well for more than 10 years of continuous use, while others run for only short periods before locking up for mechanical reasons.
3. **DC caps.** See the explanation below to understand more about capacitors.
4. **Transient spikes.** Damage may be caused to the input side of the UPS (filter/rectifier) when a transient spike occurs. During a preventive maintenance call, these parts are checked for any impairment.

Other factors that lead to UPS failure events include:

- **Lightning.** A common misconception is that a UPS constantly protects the equipment load from lightning**,** but it primarily depends on the amount of energy in the transient**.** Preventive maintenance inspections can readily identify lightning damage and any appropriate repairs.
- **UPS internal connections.** These may be affected by vibrations from the building or machinery close to the UPS. It is recommended that the UPS be scanned every three months to check for hot spots, as well as checked annually with a complete mechanical revision on the full UPS and battery cabinets.
- C**apacitors.** A typical UPS contains a dozen or more electrolytic capacitors of different types and sizes, which smooth out and filter fluctuations in voltage. Like batteries, electrolytic capacitors degrade over time. While a typical capacitor might be rated by the manufacturer for five years of round-the-clock use, it could potentially deliver up to eight to 10 years of useful life under favorable operating conditions. When a capacitor fails, there might not be any immediate visible effects, but other capacitors must compensate for the additional workload, which shortens their useful lives. In many cases, a capacitor failure will trigger the UPS to switch to bypass mode, at which time it is unable to protect downstream loads. Inspection of capacitors during preventive maintenance helps optimize their operation while also enhancing their lifespan.
- **Air filters.** Because dust may block air filters and cause a UPS to shut down due to overheating, they must be inspected every month. Replacing filters is an inexpensive component of an effective UPS maintenance plan.
- **Power supplies.** Although a UPS may have redundant power supplies, it is possible for the power supply to suffer from input voltage surges, which can cause unexpected stress and overheating. Regular inspection is recommended to detect potential issues.
- **Input filters.** Currents, parameters and physical conditions of input filters need to be reviewed and inspected. The input filter helps to reduce input total harmonic distortion (THD) from the UPS to the input line. However, depending on the amount of input line electrical noise, the filter may attempt to correct harmonic distortion for the entire installation, causing overheated cables and chokes.
- **Contactors.** Because they may collect fine dust and other resistive coatings, inspections and cleaning can prevent premature failures.
- **Sticking or welded relays.** These may go unnoticed until emergency change-of-state events occur. Periodic inspections can detect potential problems before they occur.
- **Motor operators.** These should be checked for proper operation while disengaged from the breaker, a measure completed during a routine preventive maintenance visit.
- **Firmware upgrades.** Because upgrades incorporate the latest operational enhancements, they should be completed to ensure compatibility with new load devices and to guarantee that the UPS is performing at optimum levels. A technician can complete these upgrades during routine service.
- **Transient voltage surge suppression (TVSS) integrity.** It is important to verify that metal oxide varistor (MOV) devices are functional and have not been compromised by excessive transients.

While the numerous components that comprise a UPS are clearly susceptible to failure, a preventive maintenance service plan ensures that these parts are regularly examined, greatly reducing the risk of a load loss while extending the overall lifespan of your UPS.

What is your risk of UPS failure?

Because all manufacturers' UPSs are complex devices that perform several critical power conditioning and backup supply functions, they are all subject to failure. However, by implementing a comprehensive

preventive maintenance service plan that is delivered by trained and certified technicians, you can significantly reduce your vulnerability to a load loss and extend the lifespan of your UPS.

As Chart 1 illustrates, routine preventive maintenance significantly reduces the probability of a load loss event. Through the completion of systematic inspections, a preventive maintenance plan ensures that the various electronic and mechanical components of a UPS are thoroughly evaluated, cleaned, tested and calibrated on a regular basis. Without proper maintenance, many UPSs will fail prematurely since critical components such as batteries and capacitors wear out from normal use. However, a solid maintenance plan identifies issues and greatly reduces this risk of failure.

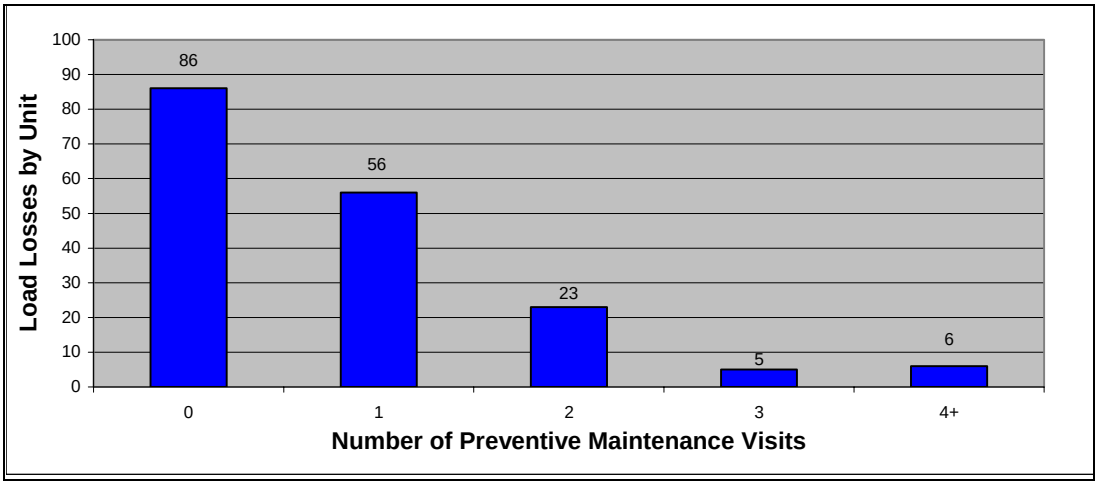

Chart 1: Powerware UPS load losses by preventive maintenance visits delivered in prior year.

Minimize interruption to your business

Lost or corrupted files. Hardware malfunctions. The inability to access the critical systems you need. All of these unpleasant consequences—just a small sampling of the possible outcomes of unexpected downtime—can significantly impact your ability to conduct business. Not to mention the potential for lost revenue and damaged reputation in the event that customer service mechanisms such as online ordering, phone systems or other sales tools are unavailable to potential customers. In many instances, there is very little lag time between system downtime and financial disaster.

However, with an effective preventive maintenance plan, your business will have access to more reliable, higher quality and more cost-effective power, all of which minimize the risks of downtime and disruption to your business.

Depending on the type of maintenance agreement you choose, trained technicians can even monitor the performance of your UPS and diagnose problems remotely, as well as respond to emergencies on a 7x24 basis, 365 days a year. In fact, if a downtime incident does occur and you have the proper service agreement in place, the problem may be fixed before you are even aware that there was one.

Maximize the performance of your UPS

Preventive maintenance is crucial in order to achieve optimal performance from your equipment. Systematic inspections, testing and cleaning by trained technicians ensure that the various electronic and mechanical components of a UPS are functioning to their maximum potential. When problems are detected and repaired before they evolve into significant—and often costly—issues, your UPS is able to deliver the level of performance you expect.

Mean Time Between Failure (MTBF), an industry-recognized measure of system behavior and reliability, uses the number and types of failures that equipment actually experiences in real applications, with calculations assuming that a system is "renewed" after each failure and immediately returned to service. A recent power quality industry study determined that without regular preventive maintenance, the MTBF of critical systems rose by 27 percent.

By implementing a comprehensive preventive maintenance service plan that is delivered by trained and certified technicians, you can reduce the number of replacement parts needed while significantly extending the lifespan of your UPS.

Enhance your return on investment

For many businesses, measuring the return on investment (ROI) of a UPS is simple, since a single downtime event can cost more than the entire expense of network protection. A solid preventive maintenance not only reduces the risk of downtime, but also decreases total cost of ownership by extending equipment life and reducing replacement costs.

A UPS maintenance plan provides additional insurance for your equipment. Considering the fact that even the slightest amount of downtime can lead to thousands of lost dollars, the out-of-pocket investment in an effective preventive maintenance plan will quickly pay for itself in ROI, not to mention peace of mind.

Decades of experience shows that regular preventive maintenance extends the life of both the UPS and its batteries. In many cases, battery life is cut in half without periodic service.

A common approach to evaluating the potential savings associated with implementing a preventive maintenance plan is to calculate an organization's cost of downtime. This evaluation should include direct and indirect costs, such as lost business opportunities, the cost of restoring servers, personnel downtime and damaged reputation. In some applications, it should also include the potential impact on safety. Most mission-critical customers are able to calculate their downtime and missed opportunity costs due to a business interruption. Safeguarding against these risks is increasingly important as insurers and risk managers are increasingly recognizing the severity of potential damages.

Basic downtime scenario assumptions

1. Duration of outage (hours)
2. Number affected by outage (people)
3. Average employee cost (per year)
4. Productivity loss (% during outage)
5. Average normal business revenue (per day)
6. Percentage of lost revenue (non-recoverable during outage)

Total productivity loss

7. Average cost per hour worked (based on 40 hours per week)
8. Average cost per employee day (based on eight-hour day)
9. Lost productivity per employee (per day)

Total revenue loss

10. Daily revenue loss (dollars)

Intangible losses

11. Reputation/goodwill (dollars)
12. Permanent lost business (dollars)
13. Compliance/reporting penalties (dollars)
14. Service contract defaults (dollars)
15. Lost opportunity (dollars)
16. Other

Total cost of outage (dollars)

When measuring ROI, the challenge is to maximize protection while minimizing cost. An effective preventive maintenance plan will help you accomplish both.

Outlining an effective preventive maintenance plan

There are a number of measures that are recommended to ensure the ongoing integrity of your UPS, including:

- Annual scheduled preventive maintenance for both the electronics and battery
- Access to rapid emergency response from trained technicians on the specific UPS models
- On-site parts inventory or local field technicians with van-stocked required parts
- Access to technical support and design engineering resources during escalation
- Remote monitoring with monthly trended reporting, 7x24 alarm notification and rapid response linkage to field technician
- Adherence to recommended parts replacement cycles, especially items that wear out more quickly such as batteries and capacitors
- Understanding of the UPS life cycle, expansion features and total cost of ownership
- Access to 7x24 call center specialists and local technicians
- Maintaining accurate records

Furthermore, since most batteries wear out every three to five years, it is critical that they are regularly inspected. And, considering the fact that the failure of a single battery jar can cause an entire UPS to fail, battery testing and replacement as needed are a fundamental component of a proper UPS maintenance plan, with most customers opting for semi-annual VRLA or quarterly wet cell battery preventive maintenance.

A new trend in battery and UPS maintenance plans is to deploy a battery monitoring system to constantly measure and report if any individual battery is out of factory specification. By allowing a qualified service provider to remotely monitor battery systems, businesses gain peace of mind knowing that expert eyes are watching and interpreting data round-the-clock. Load loss reports from customers who intended to self monitor often reveal that the monitoring output was either not being viewed or had been misinterpreted. The load loss reports also show that many times, there was not an effective process to link the bad battery alarm to a timely replacement.

A successful maintenance plan takes into account the age and actual wear of a UPS to determine where a specific device is relative to its expected lifespan. It also helps customers budget for major replacement items like batteries or capacitors, items that customers may also choose to add into an appropriate maintenance agreement. A maintenance strategy should also include an understanding of where an organization is headed, as well as its priorities for continuous operations. For example, are systems lightly loaded? Is the business experiencing unusual growth? How resilient must your operation be, and what do you consider a fast response? Is it the next day, the same day or in two hours? Once you have assessed your basic needs, you can prioritize which equipment requires maintenance agreements and what level of service is appropriate.

Typical maintenance replacement cycles

The following guidelines will help you determine the optimal replacement period for various UPS components:

Battery Life

Standby use:	Three to five years for VRLA batteries
	Wet cell battery life is variable
Cycle use:	1200 cycles at 30% of discharge
	550 cycles at 50% of discharge
	250 cycles at 100% of discharge
Capacitors:	Inspect annually. Replace every seven years or as needed.

Hot-Swappable

Fans:	Replaceable with unit online if redundant or on bypass. Verify annually, replace every seven years.
Lug terminals:	Crimp any mechanical power lugs, annual visual and thermal inspection.
Air Filters:	Replace annually or as needed.

Common UPS tests to optimize availability

The most successful UPS installations, which are measured by system availability or uptime, include prescriptive maintenance programs that are rigorously enforced. Within an effective maintenance strategy are a number of functional tests and component checks that should be conducted regularly. Specifically, an operational test or major preventive maintenance event, which cycles the UPS through its various change-of-state modes, should be conducted while monitoring key operating parameters such as voltage, frequency, current and temperature. The following operational tests are typical:

1) **Transfer to bypass and return to UPS:** This test checks the static switch and bypass breaker motor operator or contactor. The test interval should be at least annually and can be performed with the load on maintenance bypass.
2) **Battery operation and return:** Sometimes coupled with a transfer-to-generator support and return to normal, this test is typically performed monthly and tests the UPS, generator and automatic transfer switch (ATS) functions.
3) **Load balancing evaluation:** This test checks for loads on any phase that may be approaching 100 percent. To limit potential overloads, loads may be redistributed as necessary. It is important to note that any one phase may be overloaded and trigger an unexpected alarm or transfer even if the other two phases are only lightly loaded.
4) **Phase rotation/site wiring checks:** This test inspects for out-of-limit bypass alarms or site wiring faults that may have occurred as a result of normal site wiring changes or maintenance. These problems can go undetected until a transfer to bypass is attempted.
5) **Listening tests:** An experienced technician should listen for abnormal operational sounds, particularly arcing, fan-bearing noise or synchronization problems, including hunting sounds or beat frequencies. These subtle hints can easily go unnoticed by users unfamiliar with the warning sounds.
6) **Operator refresher training:** Since most power interruptions are a result of human error, constant attention should be paid to ensuring and documenting that all personnel with access to the UPS and associated switchgear have a solid understanding of the operation of the system and the consequences of any incorrect actions.

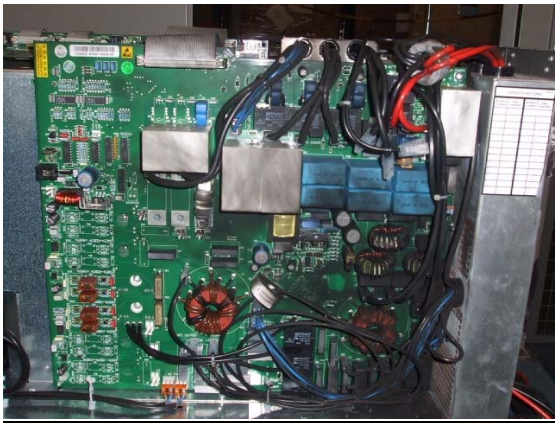

Photo 1: UPS failure due to the ingress of conductive, foreign material.

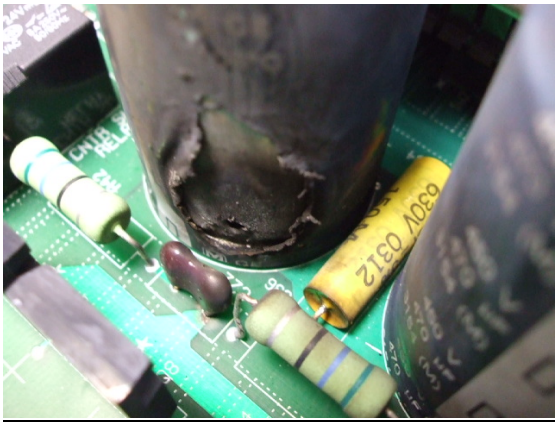

Photo 2: Random component failure.

Conclusion

Every UPS contains life-limited components that must be replaced according to the manufacturer's specifications. To ensure these parts are properly cared for and replaced when needed, regular maintenance is critical.

An effective preventive maintenance strategy can be one of the most cost-effective measures you can take to ensure the ongoing health of both your critical equipment and your overall business. Because regular maintenance practices so dramatically improve the UPS reliability and performance, while notably deterring downtime, preventive maintenance is an essential component of an end-to-end solution to keep your critical networks operating at peak performance in the face of multiple threats.