White Paper

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Your aging three-phase UPS: When to refresh, replace or run to fail

Overview

While three-phase uninterruptible power systems (UPSs) can theoretically operate for 15 and even 20 years with proper maintenance their internal electronic components can wear out much earlier especially when operating outside the recommended parameters. When a component inside of a UPS fails, it can result in an unexpected system failure and subsequent downtime. As a result, customers operating UPSs that are 10 years or older should be aware of the risks and consider three possible options:

1. **Replace the UPS**
2. **Update the existing UPS's internal electronics**
3. **Continue to operate the UPS until it fails**

In this paper, we will explain why aging three-phase UPSs are susceptible to failure; weigh individual customer considerations and circumstances; and evaluate the pros and cons of the three alternatives. Multiple factors will play a role in determining the optimal solution for a particular application. However, in order to ensure ongoing reliability and reduce the risk of downtime in a UPS that is 10 years or older, Eaton recommends that whenever possible, customers either replace the UPS or upgrade the unit's internal components through Eaton's Equipment Life Extension and Modernization services (ELEM). Engaging in an ELEM will reset the clock on a legacy UPS and yield 10 additional years of reliable operation.

In fact, the risk of protecting and maintaining a 10+ year old UPS can incur higher service and repair costs. Depending on when a UPS was introduced, parts may be harder to obtain or emergency resources may be limited.

Introduction: How aging UPSs put your operations at risk

UPS electronic components wear out over time due to dirt/dust accumulation, humidity, and heat. As the graph below indicates, the risk of failure increases as the UPS ages. Tellingly, UPS failures rank among the most common causes of unplanned data center outages, accounting for one-fourth of such events.

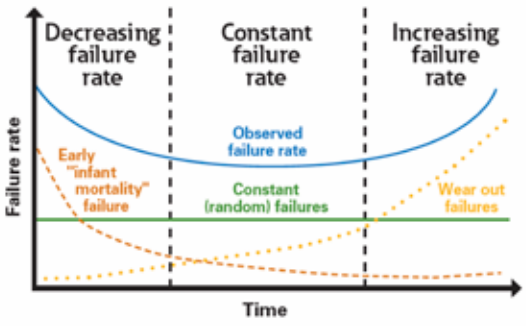


Figure 1. Typical Weibull "bathtub curve" failure rate concept. Shows an increasing risk of "wear-out failure" as a product ages.

Powering Business Worldwide

Several factors—including heat, humidity, dust and dirt—contribute to the deterioration of critical UPS components overtime

Excessive heat can make internal connections loose and brittle, as well as accelerate wear on parts such as capacitors, PC boards and wiring insulation.

Dirt and dust collection over time can limit necessary heat dissipation. This in turn can lead to the component overheating and failure.

Humidity can cause dendrites to form, bridging electrical connections and causing short circuits if operating the UPS outside of a nominal environmental envelop (22.2 °C and 50% RH).

Example of a compromised UPS electronic component.

The internal electronics that are most susceptible to wear-out failure include power modules, power supplies, control boards, interface boards, resistor boards and communication service boards. Throughout a UPS's service life, electronics and other consumable parts should be replaced on a regular schedule that aligns with the component's expected lifespan.

In many UPS designs, capacitors are located inside of power modules, which makes them difficult and extremely costly to replace. In Eaton UPSs with this type of design, the capacitors' service life is 11 years and the recommended replacement timeframe is 10 years, which aligns with the recommended replacement schedule for the entirety of the unit's electronics.

As part of Eaton's commitment to quality and continuous improvement Eaton regularly performs failure analysis on its UPS products. The following chart emphasizes the importance of proactively replacing electronics after 10+ years of use.

UPS electronic wear out failures based on Eaton 9390 UPS service incident history

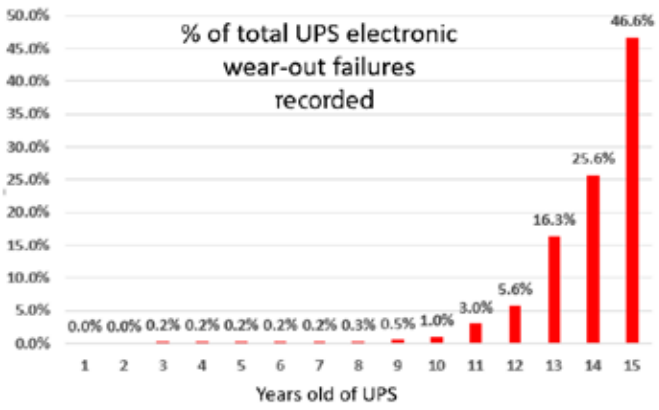


Figure 2. Total failures based on Eaton service incident history (0–15-year-old 9390 UPS's)

Figure 3. This close-up photo of an IGBT inside a power module shows the damage that results when dirt and dust accumulate over time, leading to overheating

Understanding component lifespan terms

When it comes to differentiating between the terminology used to categorize the expected lifespan of a UPS component—including its design life, service life and recommended replacement timeframe—it is important to understand what each term represents. Although each definition is unique, the terms are often interchanged throughout the industry, which can cause significant confusion.

Design life

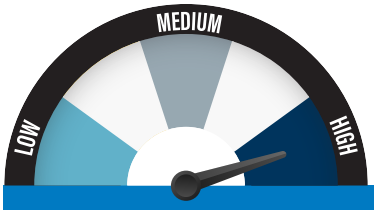
A measure of product quality, design life represents the projected lifespan of a component with the assumption that it is operating under very limited use and pristine environmental conditions like found in a laboratory.

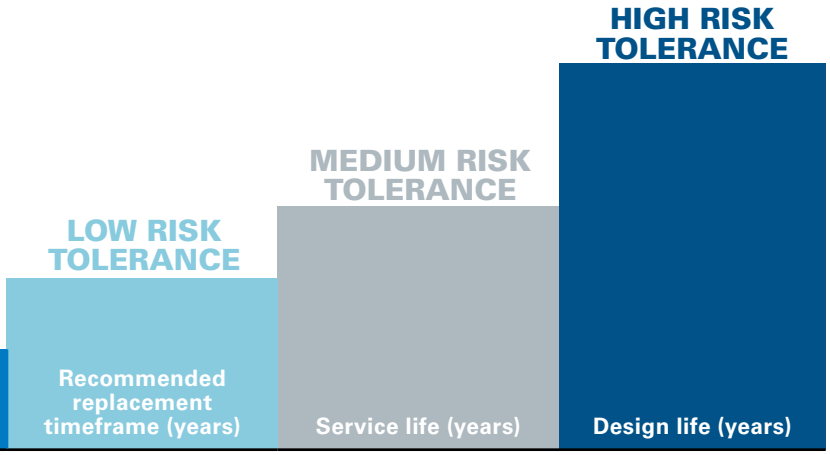
Service life

An estimate of the typical time the component will last before failure, service life assumes the component is operating under normal use and nominal environmental conditions (within the ranges listed in the product manual which are approved by engineering).

Recommended replacement timeframe

A suggestion of when to proactively replace a component, the recommended replacement timeframe allows for enough margin to avoid the component failing. It assumes the component is operating under normal use and nominal environmental conditions.





	Recommended replacement timeframe (years)	Service life (years)	Design life (years)
Consumable components			
Batteries — VRLA (on average)	4	5	10
Batteries — Wet cell (on average)	12	15	20
Batteries — Lithium (on average)	10	12	20
Fans	7	8	20
Air filters	1	1	20
Capacitors (external to power modules)	7	8	15
Capacitors (internal to power modules)	10	11	20
Electronic components			
Power modules	10	11	20
Control and interface boards	10	11	20
Resistor boards	10	11	20
Communication services boards	10	11	20

Figure 4. Average life of consumable and electronic components

Summary

While it is possible to operate a UPS past its service life, it is critical to recognize that doing so will assume more and more risk as time goes on (as demonstrated in the "bathtub curve" graph above). To better understand UPS lifespan and performance risks, let's consider how these factors might apply to a vehicle.

Assume that the tires on your car are rated for 80 000 km; this would be considered their "design life." However, as you approach 50 000 km of driving, you may find that the tires are beginning to go bald because you didn't rotate them as often as recommended, or you occasionally drove on a bumpy road, or the tires wore unevenly, or any number of other factors that can contribute to wear and tear. It is possible that you can continue to drive your automobile on bald tires for many more miles without incident. However, there is also the risk that you will not have adequate traction when you need to stop, and this danger will continue to increase over time.

Operating a UPS past its service life is very similar. Although the unit may continue to run, as each component within the UPS continues to age, the likelihood of failure increases — as does the risk of catastrophic failure.

Three options to consider for your aging three-phase UPS

Assessing individual factors

Before comparing and contrasting the three possible alternatives for what you should do with 10+ year old legacy UPSs, it is important to thoroughly assess the ongoing performance capabilities of the existing unit and its ability to meet an organization's power protection needs. Ideally, most customers would choose to install a brand-new UPS in order to reap the benefits of the latest technology and efficiency advancements. However, because every customer's situation is unique, the decision will ultimately be impacted by an individual set of goals, circumstances and constraints. Customers must take into account factors such as cost, convenience and the potential for failure in a legacy UPS. Some key considerations include:

Risk of failure/support options

First, it is essential to evaluate whether your legacy UPS can continue to meet load and runtime requirements. This will depend, in part, on the ability to access necessary service. Sometimes even UPSs that have been impeccably maintained will reach the end of their useful lifespan due to circumstances such as the inability to continue receiving OEM support or if spare parts are no longer available for the model. Furthermore, check to see if your existing service contract is able to support increasing levels of maintenance required by a legacy UPS, including an unexpected failure.

Budget constraints

Cost will almost always be a factor when considering the various UPS options. Organizations must weigh capital expenses (CAPEX) versus operating expenses (OPEX) in their decision-making process. While deploying a new UPS would require upfront CAPEX, performing an ELEM on the existing unit could be billed under OPEX. Another critical budgetary consideration is the potential for costly downtime should an aging UPS be left in service and susceptible to failure. At the same time, it is important to factor in potentially significant long-term savings in operating costs that a new, higher efficiency UPS could provide.

Time and ease of implementation

Another consideration is the time and resources that must be allotted to perform an ELEM or upgrade to a new UPS. When replacing a UPS, careful planning and execution are needed to minimize the time the UPS is offline and not protecting the critical load. Organizations must arrange to have the legacy solution removed, as well as have its parts recycled and/or disposed of. Time and personnel must also be allocated to help oversee installation, startup and commissioning of the new UPS.

Option 1:

Replace the UPS

Although replacing a legacy UPS with a new model requires a higher initial capital investment, this upfront cost must be balanced against the lower operating expenses and other advantages afforded by a new unit. Modern advancements in UPS technology have brought greater efficiency and modularity to UPSs, along with a reduced footprint, improved connectivity and a lower total cost of ownership (TCO). Combined, these benefits add significant value to organizations seeking to save time and money while lowering risk.

Advantages to deploying a new UPS include:

- **Increased reliability** — New components, coupled with modern advancements in UPS technology, translate to significantly higher reliability than what is possible from a legacy model.
- **Higher efficiency** — While efficiency varies with load level, new UPSs typically operate in the 94%–99% efficiency range and maintain high efficiency even at loads below 50%. Conversely, most legacy UPSs operate in the 80–92% efficiency range. Using a net-present-value calculation, the chart below illustrates the power savings from a modern UPS system compared to a legacy unit. When also implementing Eaton Energy Saver System (ESS) or Variable Module Management System (VMMS), the savings are even greater — reducing energy costs by more than $230,000 over a 10-year period.

	Legacy UPS (750 kVA)	Modern UPS (750 kVA)			Savings with Modern UPS		
	Double conversion	Double conversion	VMMS	ESS	Double conversion	VMMS	ESS
Efficiency at 30% load	89.8%	96.3%	96.7%	99.2%	6.5%	6.9%	9.4%
Annual Power Costs	$175,373	$163,495	$162,879	$158,755	$11,878	$12,494	$16,618
Annual Cooling Costs	$70,149	$65,398	$65,152	$63,502	$4,751	$4,998	$6,647
Annual Power & Cooling Costs	**$245,522**	**$228,893**	**$228,030**	**$222,257**	**$16,629**	**$17,492**	**$23,265**
10 Year Power & Cooling Costs	**$2,455,224**	**$2,288,930**	**$2,280,304**	**$2,222,572**	**$166,294**	**$174,920**	**$232,652**
Net Present Value (NPV)					**$122,305**	**$128,650**	**$171,111**

Figure 5. Efficiency savings example 750 kVA

- **Smaller footprint** — New UPSs are typically 10–30% smaller than legacy models, which can free up valuable real estate within a data center or other facility.
- **Increased capacity** — With modular UPSs, capacity can be increased with expanding load requirements, enabling a pay-as-you-grow approach.
- **Improved technology** — Modern UPSs are designed with a range of advancements that enhance functionality, including powertrain controls, HMI display and embedded diagnostics.

The potential disadvantages of replacing an aging UPS with a new model include:

- **Installation/deinstallation expenditures** — When installing a new UPS, the cost for materials — such as conduit, wiring and circuit breakers, transformers, maintenance by-pass, distribution, and battery cabinets — can be significant. The cost of rip-and-replace with electrical installation and deinstallation typically rings in at about 1/3 of the total material costs. Labor expenses must also be factored in, like rigging to remove and install the new UPS.
- **Time offline** — The transition from a legacy UPS to new unit can take weeks to months, with disruption to operations sometimes unavoidable. The actual cutover from the old system will require the UPS to be off-line in by-pass mode typically for a minimum of three days for the electrical contractor and rigger to complete the installation and the new UPS to be started up and commissioned.

Option 2:

Update the electronics inside of the legacy UPS

Customers who wish to mitigate the risks associated with a legacy UPS can reset the clock and completely revitalize the unit through Eaton's ELEM services. The process installs new electronics within the frame of the existing UPS. Consumable parts such as capacitors, fans and batteries can also be replaced as needed at the same time as applicable. The service includes a 1-year warranty on parts and labor, Cyber Secured Remote Monitoring, as well as the option to purchase full-service coverage — reviewed annually for potential extension — for a minimum of 10 years after the installation.

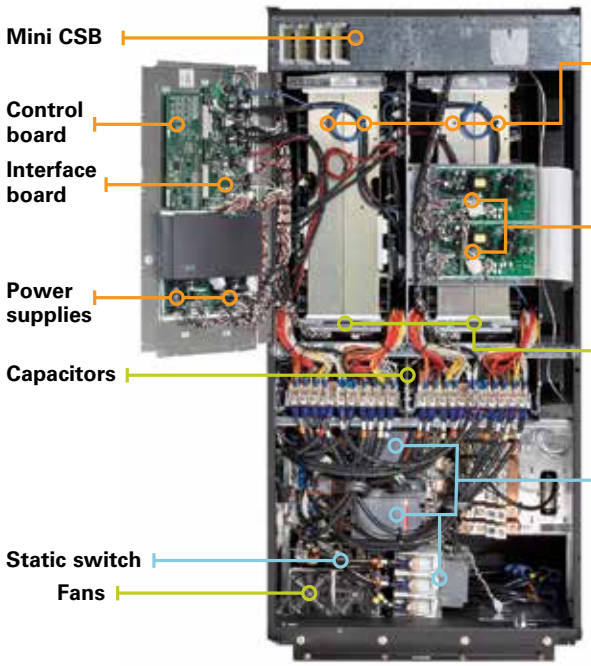
Advantages to ELEM include:

- **Cost savings** — Since an ELEM does not necessitate changes to the site's electrical installation, it typically results in savings of approximately 1/3 in total site costs compared with installing a new UPS.
- **No change to existing footprint** — Even though the electronics are completely updated by an ELEM, the legacy unit occupies the same aisle space and floor dimensions, with no modifications required.
- **Quick implementation** — To perform an ELEM, the legacy UPS is placed in maintenance bypass during the retrofit process, which only requires one day, significantly less than a full UPS replacement.
- **Optional upgrades can be performed at the same time** — If desired, valuable additional services can be performed in conjunction with an ELEM. Options include adding Eaton's Energy Saver System (ESS), which bolsters efficiency in a legacy UPS by 7-12 percentage points, and/or kVA upgrades that add capacity.
- **Ability to reuse integrated accessories/batteries** — When an ELEM is performed, many existing UPS accessories can be reused, including battery cabinets, maintenance bypass cabinets, distribution cabinets and transformers. If the batteries are approaching or beyond their recommended replacement timeframe, they can be changed out, while reusing the existing cabinet.
- **Billable as an operating expense** — Because allocating OPEX is often viewed more favorably than CAPEX by financial management, an ELEM can represent an easier approval process compared to purchasing a new UPS.
- **Green and sustainable option** — Reuse represents the highest form of recycling, with the UPS's sheet metal, framework, copper buswork, conduit, power and most control wiring all retained. By performing an ELEM, a UPS's eventual recycling is delayed by up to 10 more years.

Disadvantages to performing an ELEM include:

- **Similar costs** — Although the price tag will be comparable to the material cost of a new UPS, customers will not gain the benefits of the latest UPS technology.
- **Shorter OEM service contract** — The availability of the contract coverage may be less than that provided with a new unit.

The Eaton 9390 ELEM is for customers with 10+ year old 9390s who want RESET set the clock and get 10 more years of service life.



Inside view of 9390 120–160 kVA UPS

Additional services included:

- Cleaning of contactors and wiring (replacement as necessary)
- UPS system calibration, functional testing and reporting
- 1-year warranty (7x24, 8 hour response, parts and labor)
- Cyber Secured Remote Monitoring (1-year subscription)
- 10-year minimum entitlement to purchase full-service coverage

Optional services:

- ESS Upgrade to 99% efficiency (as applicable)
- kVA Upgrade for additional capacity
- Full onsite commissioning/load bank testing services

Color key:
- Replaced during ELEM (electronics)
- Optionally replace at same time (consumables)
- Stays (replacement not necessary)

Figure 6. Update the electronics inside of the legacy UPS

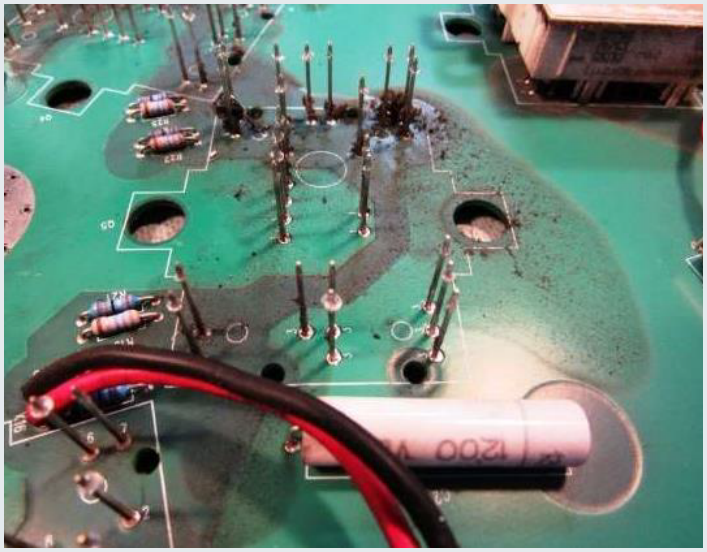


Figure 7. Circuit board inside a UPS power module that failed due to short circuit.

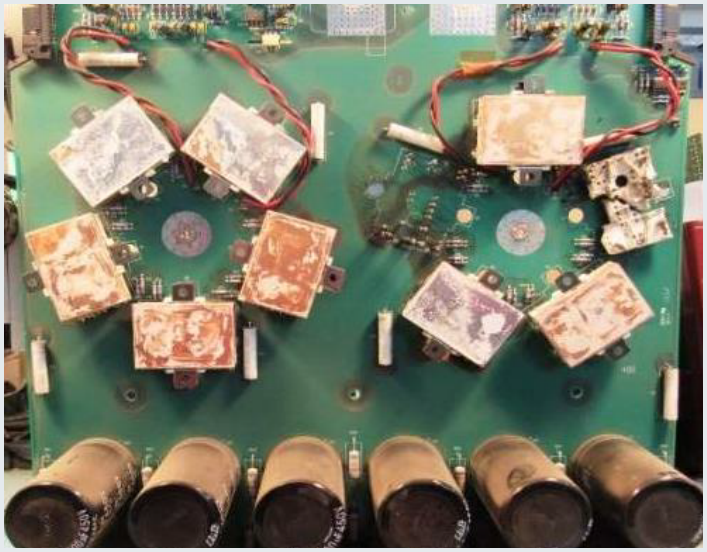


Figure 8. dirt and dust accumulation on capacitors and other components inside a UPS power module.

Option 3:

Operate the existing UPS until it fails

While trying to squeeze every last ounce of operation out of a legacy UPS may seem like a good idea, the option brings with it significant risk. Depending on which component that fails, it could result in an immediate transfer of the critical load to utility bypass or to other UPS modules in a parallel redundant system. In a single module, non-parallel UPS, a transfer to bypass would leave the critical load exposed. Furthermore, when a UPS electronics component does fail, a service call must be scheduled in order for a replacement to be completed.

Advantages to continuing to operate a legacy UPS include:

- **Postponing the cost of proactive replacement** — The customer will use the UPS to its full capacity until the unit fails and needs to be replaced.
- **Redundant units may support load during a failure** — For customers with adequate redundancy (at least N+1 or 2N), a single UPS unit failure will not cause a critical load failure since the other unit will support the load. However, the load will no longer have redundant protection.
- **Failures might be covered by service contract** — For customers with OEM service contracts, if the system fails, and the UPS is operating within the nominal environment, the OEM will replace the failed components.
- **Leverage Cyber Secured Remote Monitoring to mitigate risks** — Eaton offers a cloud based monitoring service to manage both alarms, UPS health and component risk. Cyber Secured Monitoring acts as an extra set of eyes where Eaton power experts can use analytics to determine if a UPS needs attention by a trained factory service technician. Key benefits to Eaton monitoring include real-time data delivered to customers via a mobile or laptop device, reporting, 24x7 critical alarm notifications via phone and dispatch of local service technicians. Deploying Cyber Secured Monitoring in addition to a service strategy to manage aging component risk adds an extra protection layer.

Disadvantages to operating a UPS that is 10 years or older include:

- **Downtime can be devastating** — Even a momentary blip in power can trigger costly downtime and serious ramifications, from equipment damage and data loss to tarnishing a company's reputation. Consider that the average cost of data center downtime currently rings in at $9,000 per minute, while a recent survey of the Fortune 1000 by IDC tallied the average cost of an infrastructure failure at $100,000 per hour, and the total annual cost of unplanned application downtime at $1.25 billion to $2.5 billion.
- **More expensive service contracts** — Obtaining a service contract for a UPS that is more than 10 years old will typically be more expensive than one for a newer UPS. This is due to the likelihood of failure increasing as the unit ages, combined with the cost of spare parts increasing over time.
- **The need for extreme vigilance** — An organization that assumes the risk of operating a legacy UPS must proceed with great caution and adhere to careful planning. Facilitating close cooperation between facilities and IT personnel is paramount, as is ensuring that a qualified team is in place to minimize the impacts of the unit's imminent and inevitable failure.

Conclusion

In a perfect world, most customers would choose to install a new UPS that would enable them to harness the latest-and-greatest technology advancements. However, when considering the best course to take with an aging UPS, there are numerous circumstances and constraints that must be weighed. For some customers, the optimal solution — for both cost and convenience — is to extend the life of the existing installation. For others, it may be to assume the risk of UPS failure, especially if that threat is mitigated by a redundant system. Whatever you choose, Eaton has the solutions and services to extend the reliability of an existing UPS or upgrade your entire UPS system. For more information, please visit, **eaton.com**.

About Eaton

Eaton's mission is to improve the quality of life and the environment through the use of power management technologies and services. We provide sustainable solutions that help our customers effectively manage electrical, hydraulic, and mechanical power – more safely, more efficiently, and more reliably. Eaton's 2020 revenues were $17.9 billion, and we sell products to customers in more than 175 countries.

About the author

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Option	Circumstances that support
Buy new UPS	• Vendor no longer supports legacy UPS • Replacement parts are no longer available • Desire to take advantage of new UPS technologies • Capacity does not meet current/future needs • Efficiency does not meet current/future needs • Unserviceable parts have failed or are likely to fail • Available CAPEX budget • Can sustain time offline required for full replacement
Upgrade existing UPS	• Cannot sustain extended time offline required for full replacement • Desire to avoid electrical contractor, project management, rigging • Desire to keep same footprint / tight room with limited aisle space • Desire to bill as an operating expense (OPEX) • Key replacement parts remain available • Desire a green solution
Run existing UPS to fail	• Existing UPS has high level of redundancy • Service contract covers sudden UPS failure • UPS meets current and future capacity needs • No budget available

Figure 9. Summary of options of what to do with your aging 3PH UPS

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