Total Cost of Ownership for Real World Power Protection Infrastructure

Comparing Centralized vs. Distributed Power Systems

Introduction

Ultimately, the true cost of implementing a power protection infrastructure is measured over the useful life of the equipment and varies based on the scope of the installation. Because many of today's information technology (IT) systems use distributed architecture, it is often assumed that the supporting critical power infrastructure should be distributed as well. A real world analysis of Total Cost of Ownership shows that, from a number of different perspectives, a centralized power solution is often the most cost effective approach while offering the added benefits of increased reliability and simplified monitoring.

This paper discusses key aspects of the power infrastructure involving uninterruptible power supplies (UPS) and associated hardware. It uses real-world scenarios to demonstrate the advantages and disadvantages of various configurations.

Power System Deployment

Any significant installation of hardware in an IT environment can be disruptive to critical IT operations, especially installations involving the power that makes everything else work. On the surface, it may appear that installing a UPS or group of UPS systems in the bottom of each equipment rack might be the easiest approach. However, in most deployments that involve more than a couple of racks of equipment, taking a centralized approach not only streamlines requirements for IT personnel, it all but eliminates interruptions to overall operations.

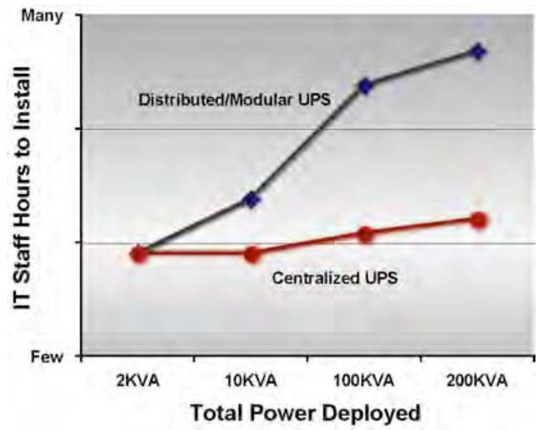


Figure 1. *IT staff time required to deploy centralized vs. distributed power systems*

In a centralized configuration, virtually all of the power-related work is performed by contractors who install a UPS and power distribution sized for the needs of the organization. Because they complete these installations independently of the IT staff, there is very little disruption to other IT functions beyond a one-time "transfer of power" when the new power infrastructure is deployed. Once these power contractors complete their work, the IT staff can focus on their jobs with power essentially built-in to the data center.

Typically, a distributed system takes about one day per rack to deploy with most of the work performed by IT personnel who are generally not as familiar with power issues as they are with their core systems. Because of the ongoing nature of the work, multiple systems can be down frequently over many days as different components are powered up and down.

Power Density & Space Utilization

As mainframe and minicomputers have given way to distributed network architectures, rack designs have been optimized to accommodate high-density computing. The most cost effective use of this rack space is to populate it with computers and their core peripherals. Because power equipment does not require the frequency of access or rear access that other IT equipment needs, it can easily be located in a less expensive area. In fact, power can actually be more secure when located away from more heavily accessed areas, removed from accidental or intentional intrusions.

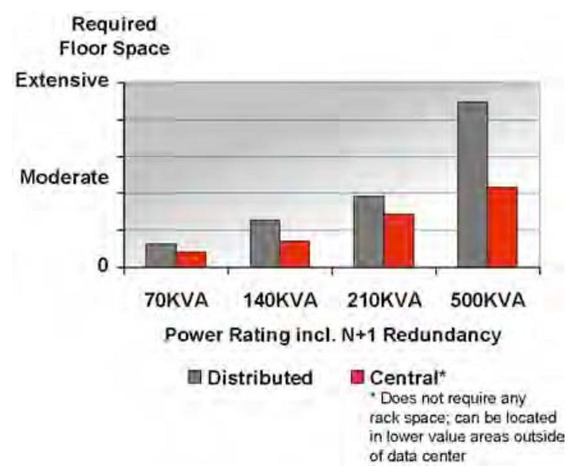


Figure 2. *Space requirements for UPS systems requiring rear access add a hidden cost to power installations*

A centralized UPS can be sited away from traffic areas, in a separate room or in a corner, and actually reduce total space required for the overall installation by eliminating the need for rear access as well as inefficient use of rack space. While centralized UPSs may seem large, the aggregate space requirement for distributed systems typically ends up being even larger and occupying considerably more footprint. (See Figure 2) **Rear access requirements, common in most distributed systems, can actually triple the space needed**

for installation. When that space is located in prime IT areas, the real cost of an installation can increase rapidly.

Another hidden cost involved with distributed installations is the interconnect cabling. In a distributed environment, users often find that they are given only a single-source for proprietary interconnect cables. Meanwhile in a comparably sized centralized installation, contractors generally install the standard wiring according to the National Electric Code (NEC) after a competitive bidding process that assures the most cost effective installation.

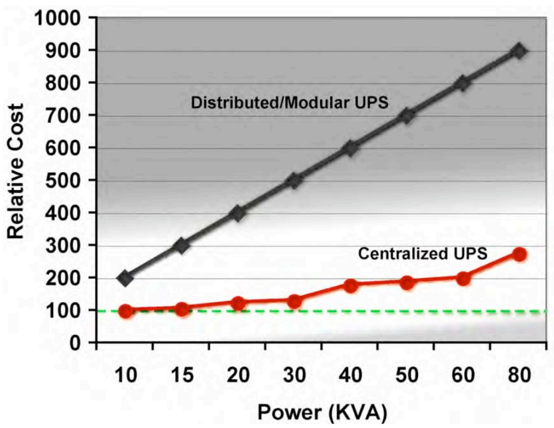


Figure 3. *Cost per kW increases as power requirements increase in a modular system, while cost per kW actually decreases in a centralized installation*

Expandability & the Rightsizing Myth

Simply stated, distributed power installations are more expensive on a cost per kilowatt basis than a centralized installation. While a centralized installation may be fractionally more expensive to build with excess capacity to allow for future growth, expansion of a distributed system can be extremely costly in terms of equipment purchase as well as downtime and disruption to power during subsequent installations. In a distributed installation with dozens, perhaps hundreds of individual UPS systems, users are paying for what amounts to duplicate or multiple user interfaces as well as packaging, cabling and mechanical features that add nothing to reliability.

Planning ahead is essential for any large installation. In the case of power infrastructure, this includes making accommodations for proper wiring, distribution and circuit breakers that are all extremely expensive to add after the fact. Whether the installation involves one 200 kVA UPS or one hundred 2kVA systems, the electrical service to the area must be sized for the total current required. Clearly, it is not practical to increase the overall service to the facility in 2kVA increments and, in most cases, neither is it practical or cost effective to add UPS systems in a piecemeal fashion. Adding power equipment to racks as power needs invariably grow can result in downtime as connected equipment must be taken offline. Rightsizing centralized power from the beginning facilitates “plug-and-play” IT installations with virtually no disruption to nearby equipment.

In some ways establishing power requirements is similar to determining cell phone minute usage in an organization. Users sharing a central pool of power (or minutes) tend to use that resource more effectively because the heavier users and lighter users balance each other. If every rack contains a 3kVA UPS with each rack using 1.5 to 2.5kVA of steady state power and no more than 3kVA of peak power during startup, it is easy to see that quite a bit of excess power is being wasted. When a piece of equipment added to a rack causes the total power requirement to exceed 3kVA, the configuration must be completely re-engineered to accommodate a small increase in power.

Efficiency

The efficiency of a power system is almost invisible to the user, but the operating cost difference using a high efficiency UPS can equal the cost of the entire power system in three to five years. Not only does lower efficiency boost utility bills, the wasted power shows up in the form of heat that requires added air conditioning that increases infrastructure costs and results in still higher utility bills.

Energy efficiency of a UPS is the difference between the amount of energy (as documented by the utility meter) that goes into the UPS versus the amount of useful energy that is available to power the connected equipment. While all UPS systems lose some energy in the form of heat when it passes through the internal UPS components, centralized systems — with their optimized designs and reduced parts count — typically have a 2 to 10% efficiency advantage compared to distributed systems. Although this may not sound substantial, the fact that UPSs operate 24-hours per day every day means that even a small improvement in efficiency can translate to tens of thousands of dollars in savings in only a year or two.

In addition, centralized UPSs are designed to maintain efficiency with different types of loads (connected equipment) and varying load levels. Distributed systems often specify high efficiency when fully loaded but typically operate at a fraction of their rated capacity where their efficiency is considerably lower.

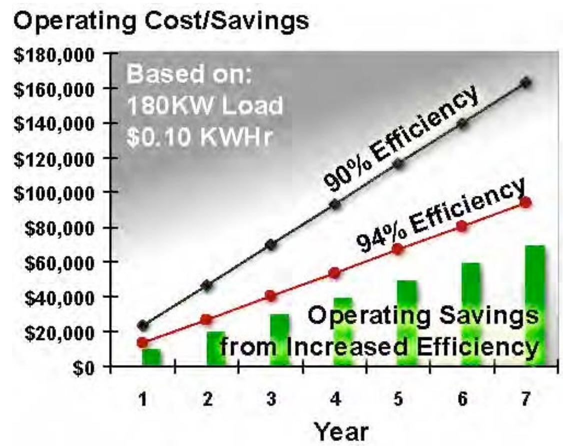


Figure 4. *Operating efficiency in centralized vs. distributed systems results in considerable cumulative savings over the life of the UPS*

Figure 5. *Real world or actual efficiency is often different from the "ideal" efficiency published in spec sheets. Efficiency is usually much lower at partial loads where most UPSs operate, or when powering electronic loads.*

Reliability

While marketing materials may boast of superior reliability, every engineer knows that the statistical reliability of a given piece of equipment can be calculated by multiplying the number of components by the mean time between failures (MTBF) for each component.

In simplest terms, the more components contained in any given system, the lower the reliability. At the same time, increased parts counts generally translate to higher costs. In a simple analogy, it is easy to see that an array of four light bulbs each supplying 25 Watts will cost more while requiring added time and cost to install and maintain compared to one 100 Watt light bulb.

By definition a distributed configuration has more parts — and more parts that can fail. In fact, the basic component count in a large UPS is not substantially different than that in a small UPS. But kilowatt-for-kilowatt one large UPS has far fewer components and those components are far more robust than those in multiple small UPSs needed to supply the same power. Even if the smaller devices had a higher individual MTBF (which they don't), the increased number of devices leads to an inherently less reliable system overall.

Component Quantity X Quality Factor X Failure Rate = MTBF

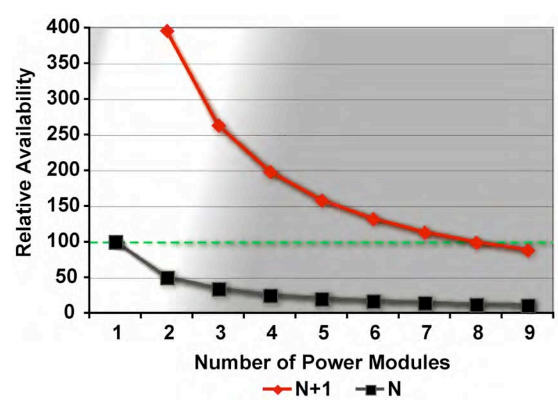


Figure 6. *Mean time between failures for centralized vs. distributed systems*

Additionally, because the large UPS incorporates more robust components and a system design geared towards heavy-duty operation, centralized systems have greater fault-clearing ability – as much as 200% of rated output – that leads to inherently higher reliability. Power disturbances such as short circuits that will shut down lesser systems are barely noticeable in a centralized UPS.

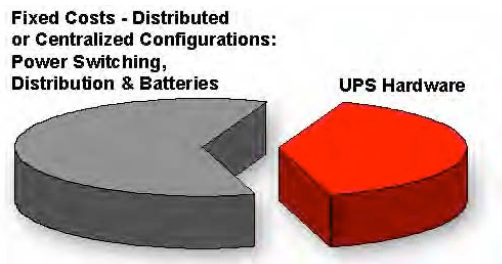


Figure 7. *UPS hardware as a percentage of total power system cost*

Monitoring & Integration

The ability to monitor the operation of any UPS is an important factor in overall uptime for any installation. A single 200kVA UPS has one interface on the UPS front panel. In addition, it can easily be monitored remotely by a variety of means from pager or e-mail notification of power alerts to integration with network management system (NMS) consoles that will display a host of system parameters. The same is true of most high-quality individual distributed UPSs. The problem occurs when an installation that could be supported by a single UPS is instead supported by dozens or hundreds of smaller UPSs. Network managers will still receive notification of problems with the system, but with multiple UPSs, it is not always easy to identify which device needs attention. Oftentimes, IT managers don't even know where all of the UPSs are located. Moreover, in the event of widespread power disturbances, it is not uncommon to have all of the UPSs in a given area broadcasting cautionary notifications simultaneously. In such a circumstance an IT manager would literally be inundated with alert messages.

In terms of integration, it is important to note that the UPS itself makes up a relatively small part of a total power installation. Whether centralized or distributed, batteries and power distribution make up about 60% of a typical installation. When power requirements expand, these components are actually easier to add on an as needed basis than the UPS hardware in most cases.

Business Lost =
(Revenue/365) X Downtime (days)

Lost Production Capacity =
Units Not Produced X Unit Price

Net Revenue Lost =
Units Not Produced X
(Unit Price – Unit Production Cost)

Figure 8. *Compare the cost of a factory service contract that assures maximum availability to the cost of lost business, revenue or production capacity*

Maintenance & Service

Even the most reliable power protection system has components with a finite life — especially batteries. Yet few IT organizations have staff trained to deal with the maintenance, troubleshooting and service of power systems. Not only does preventive maintenance prolong system life, the availability of factory-trained service engineers can be vital to minimizing downtime. Surprisingly, most resellers of UPS systems used in distributed applications either require depot repair for the UPSs or offer only third-party service by engineers who typically specialize in more lucrative computer repairs or other types of service. For critical installations a 7X24 service contract — with factory-trained engineers — adds to uptime far more than it might add to total cost of ownership.

Battery Maintenance & Configuration

Batteries are the weakest link in any UPS system, centralized or distributed. However, for a number of reasons, batteries have a longer life expectancy in centralized systems. It is not uncommon to see batteries in large systems last 5 to 7 years as opposed to 3 to 4 years in distributed systems.

Due to different cost structures and size constraints, batteries in centralized systems are often drop-shipped directly from the battery manufacturer and tend to be of a higher quality than those in smaller UPS systems. In addition, centralized battery banks are generally designed to facilitate regular inspection and maintenance without disruption to connected equipment. The combination of higher quality batteries and ease of preventive maintenance is an important factor in increased battery life. In addition, the double-conversion technology typically used in centralized UPSs minimizes battery cycles compared to the line interactive systems commonly used in distributed installations that actually cycle the batteries to provide power conditioning. In any battery, fewer discharge cycles translate to longer battery life.

Since battery cost is a significant part of the cost of any UPS, maximizing battery life is a key element in reducing total cost of ownership.

Even with the best batteries, careful monitoring and proactive maintenance are critical to assuring uptime. It will always be easier to monitor and maintain a centralized system than dozens of separate battery installations. Since every installation contains multiple batteries, monitoring of multiple battery systems can be even more challenging than monitoring multiple UPS systems. In centralized environments, battery monitoring is simplified because more sophisticated monitoring options are available for large systems and also because the cells are typically in one place rather than tucked into every equipment rack in the facility.

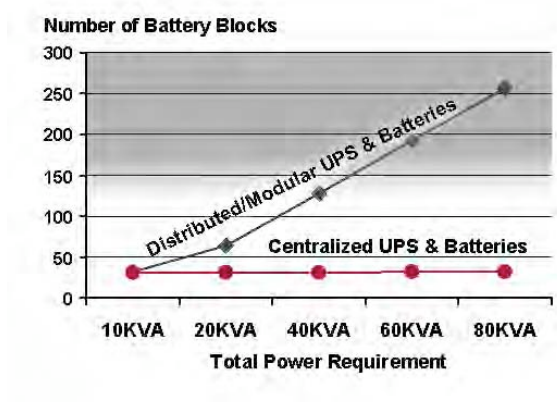


Figure 9. *Increased number of battery blocks in distributed installation leads to increased initial costs as well as higher battery failure and cost for maintenance.*

Conclusion

The fact that a single small rack-mounted UPS seems inexpensive and easy to install can mislead users to a false sense of economy. In reality, the reduced space requirements, robust design, industrial-strength components, greater operating efficiency, optimized battery systems, superior reliability and lower cost per KVA strongly support use of centralized configurations. When the complete installation, operation, maintenance and upgrade costs are considered, the savings of a centralized UPS installation are considerable.

Centralized vs. Distributed Power Infrastructure Comparison Summary

	Centralized	Distributed
Deployment	Performed by contractors familiar with power, minimal disruption to connected IT equipment	Performed by IT staff; takes approx. 1 day/rack to install; IT equipment down during installation
Space Utilization	Uses no IT rack space; can be located, away from heavy traffic areas; minimal access required – semi-annual preventive maintenance; front access only	Occupies prime IT rack space; usually requires rear access and larger overall footprint when total facility usage is considered
Rightsizing	Lower cost per kVA given equivalent total kVA ratings (ie. One 200kVA UPS vs. one hundred 2kVA UPSs)	May have lower initial cost by installing fewer systems; quickly becomes more expensive with any changes.
Expandability	Recommend buying UPS with anticipation for inevitable growth; easy & inexpensive to add batteries and power distribution	If facility was not sized for increased service, upgrades are especially costly & disruptive. Sharing power between racks is not practical, so it is difficult to optimize power for each rack
Efficiency	94% at full load and as high as 95% with typical partial loads. A 5% increase in efficiency can save upwards of $3,000/yr for a 100kW load.	As little as 83% at full load and potentially even less with partial loads. Lower efficiency also produces heat that requires added HVAC.
Reliability	Lower parts count = superior MTBF, documented reliability	More complex systems are more failure-prone
Monitoring	Far easier to monitor one central system than many	IT mangers often don't even know the location of all UPSs
Integration	UPS is only ≈40% of total power system cost	Batteries & power distribution may cost the same
Maintenance	Easier and less time-consuming to maintain with single location; better maintenance = <uptime	Multiple locations add to maintenance requirements; less maint. = <downtime
Service	Factory, onsite service available	Limited factory service, depot or 3rd Party service
Battery Maintenance & Configuration	High quality batteries in a centralized location allow easier maintenance, yielding longer battery life and lower cost	Higher volume of smaller, batteries scattered throughout the facility make battery maintenance complex and costly yielding shorter battery life and higher battery replacement cost

References

Cougias, D., Heiberger, E. L., & Koop, K. (2003). *The Backup Book: Disaster Recovery from Desktop to Data Center* (3rd ed.). Chicago: Schaser-Vartan Books.

EPRI. (2003). *Life Cycle cost Analysis of Power Quality Mitigation Devices* (No. 000000000001001674): Electric Power Research Institute.

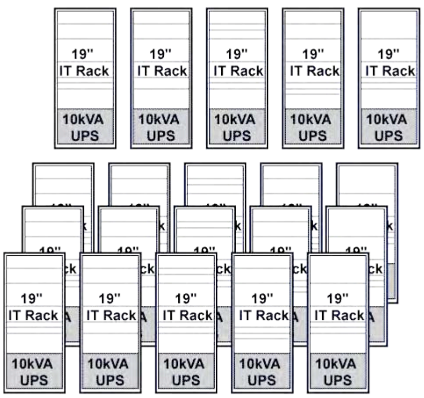
Miseta, E. (2004, June 2004). Protect Entire Data Center with Single Power Supply. *Business Solutions*, 19, 80-81.

Sample Total Cost of Ownership Scenario

300kVA Centralized Power Infrastructure

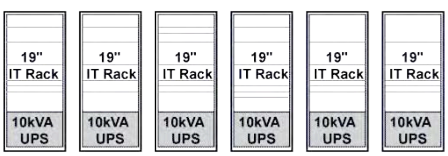
UPS	$ 34,000
Batteries	$ 16,000
Distribution	$ 16,000
Operation/5 yr	$ 17,660
5-Year Total	$ 171,960

200kVA Distributed Power Infrastructure



UPS	$ 50,000
Batteries	$ 30,000
Distribution	$ 30,000
Operation/5 yr	$ 98,110
5-Year Total	$ 208,110

Add 60kVA of Distributed Power



UPS	$ 15,000
Batteries	$ 9,000
Distribution	$ 9,000
Operation/5 yr	$ 23,547
5-Year Total	$ 56,547

Assumptions:
Typical end user cost for hardware
Utility cost = $0.14 per KWh
UPS is powering unity power factor loads at 80% capacity.

Important Note about Floor Space Requirements:
Due to the diversity of configurations and site scenarios, space requirements have not been factored into the sample costs above. It is important to note that total space requirements increase significantly in a distributed installation and *floor* space requirements increase even more because computer racks require at least 30 inches of clearance for rear access. Well-designed central UPS systems typically do not require rear access and can be situated out of the way, next to a wall or other barrier, maximizing valuable rack space for critical servers and other equipment that does require rear access.