Essential Power System Requirements for Next Generation Data Centers

White Paper #4

Revision 4

Executive Summary

Effective mission critical installations must address the known problems and challenges relating to current and past data center designs. This paper presents a categorized and prioritized collection of power system challenges and requirements as obtained through systematic user interviews.

Introduction

Despite revolutionary changes in IT technology and products over the past decades, the design of power infrastructure for mission critical installations like data centers and network rooms has changed very little since 1965. Although IT equipment has always required electrical power, the way that IT systems are deployed today has created new power-related problems which were not foreseen when the powering principles for the modern data center were developed over 30 years ago[1]. In this paper, a systematic approach of identifying and classifying user problems provides insight regarding the nature and characteristics of power systems in next generation mission critical installations.

Survey

A survey of management personnel relating to mission critical installations was conducted, interviewing corporate CIO's, Facility Managers, and IT Managers. Over 150 people were interviewed from over 90 different organizations including Fortune 1000 companies, Government and Education, and Service Providers. Approximately 50% of customers interviewed were from North America, 20% from Europe, and 30% from Japan, Pacific, Australia, and Asia (JPAA) region.

The one year survey utilized "Voice of the Customer" techniques, which relies on data collection of verbal and/or written responses to open-ended questions. This provides extremely unstructured responses, with the advantage that the responses are not limited or constricted by preconceptions within the question. During the course of the survey, some of the questions were expanded and/or changed in order to clarify ambiguous responses.

Results: Power System Challenges in Mission Critical Installations

Survey responses were grouped according to common concepts, and for each group a solution requirement, corresponding to a challenge for mission critical installation design, was derived. This process identified 22 core challenges. These core challenges were then further grouped according to theme into the following 5 key theme areas:

- Lifecycle Costs
- Adaptability / Scalability
- Availability
- Manageability
- Maintenance / Serviceability

For each theme area, the challenges, underlying problems, and power system requirements are presented in tabular form. The highest priority problems are listed first under each theme. The priority was determined by combining number of mentions weighted by priority as expressed by the respondents.

Lifecycle Cost Challenges		
Challenge	**Underlying problems**	**Power System Requirements**
Optimize capital investment and available space	System requirements are difficult to predict and systems are frequently oversized.	Modular systems that grow with the requirement.
Accelerate speed of deployment	The planning and unique engineering involved takes 6-12 months, which is too long when compared with the planning horizon of the organization.	Pre-engineered solutions that eliminate and/or simplify most planning and engineering.
Lower the cost of service contracts	Service contracts on unused or underutilized equipment is wasted.	Right sized systems that can be scaled rapidly with changing requirements would reduce oversizing and the wasted service contracts associated with underutilized equipment.
Recover from false start or low ROI projects	It is very difficult to downsize or move a project once it is underway, but changing business issues frequently require such changes.	Modular and portable power infrastructure that can be moved to other facilities when required.
Bill users for power	It is desirable but currently impractical to charge users based on their actual power consumption.	Power metering

The survey found the lifecycle cost challenges were the most important requirement, particularly for respondents from top level management in their organizations.

The survey revealed a pattern of oversizing and underutilization of data centers and network rooms in all types of businesses. This key issue is further studied in APC White Paper #37: “Avoiding Costs From Oversizing Data Center and Network Room Infrastructure”

Adaptability / Scalability Challenges		
Challenge	**Underlying problems**	**Power System Requirements**
Reduce the extensive engineering required for custom installations	This engineering is time consuming, expensive, a key source of downstream quality problems, and it makes it very difficult to expand or modify the installation later.	Pre-engineered solutions that eliminate and/or simplify most planning and engineering.
Plan for a power density that is increasing and unpredictable	Industry projections of power density requirements show great uncertainty but new data centers must meet requirements for 10 years.	System design that can be easily adapted, even retrofit, to power high density racks which might be isolated cases or widespread in the future
Adapt to ever-changing requirements	Different power requirements, voltage requirements, outlet requirements, even the need for DC may occur at any time in any rack.	A rack power infrastructure that allows quick and tool-less changeover for different voltages, power capacities, outlets, and DC.
Manage the proliferation of branch circuits	In a dual path system there may be 6 or more branch circuits per rack, and these circuits are constantly being re-wired. It is very difficult to keep track of this high quantity of changing branch circuits and particularly to determine if they are overloaded.	Higher power distribution to the rack, eliminate re-wiring, and provide local and remote metering.
Cope with the increasing number and poor quality of circuit breakers	Data centers and network rooms use the same types of breakers for branch circuits that are used for residential/light industrial applications. These breakers are not of high quality, frequently do not meet their specifications, and are used in such a high quantity that their shortcomings become a statistically significant part of data center down-time.	Better quality breakers, pre-installed and tested.

The solution requirements to meet the Adaptability Challenges share many features in common with the solution requirements for life cycle costs. In particular, pre-engineered, standardized, and modular solutions are needed.

Many issues related to adaptability relate to the architecture of the power distribution system to the rack. This subject is discussed in detail in APC White Paper #29: “Rack Powering Options for Data Centers and Network Rooms”.

Availability Challenges		
Challenge	**Underlying problems**	**Power System Requirements**
Minimize human error	Uniquely engineered, poorly documented systems. Changing requirements require re-wiring of live systems.	Pre-engineered solutions that have comprehensive documentation and mistake-proofing features.
Minimize points of failure between UPS and critical load	Large centralized systems remotely located from the load with complex output power distribution systems, creating the need for additional redundancy features in the distribution system such as static transfer switches.	Systems that minimize the number of breakers and amount of wiring between the UPS and the loads.
Reduce failure points that drop customers simultaneously	Large centralized systems with complex coordination among circuit breakers create a condition where faults can unexpectedly propagate across systems.	Systems that minimize the number of breakers and amount of wiring between the UPS and the loads, and that are pre-engineered and tested for breaker coordination.
Eliminate harmonics	Large centralized UPS system that present a large harmonic load to the utility, switchgear, and backup generators; creating unexpected interactions and requiring oversizing. Uncertainty regarding the magnitude and effects of harmonics in the IT loads.	UPS systems with input power factor correction. Loads that have input power factor correction. Distribution equipment that is pre-engineered to handle harmonics and is protected against harmonic overload problems.
Learn from past problems and share learning across systems	Uniquely engineered systems where learning on one system cannot be transferred to another. No clear way that solutions for one customer's problem are communicated to other similar customers.	Pre-engineered standardized systems where learning is shared through manufacturer notifications and automatic upgrade procedures.

Survey respondents universally identified human error as the dominant problem relating to availability. The Uptime Institute has reported that over 50% of all load drop events in data centers are caused by human error. Respondents expressed frustration at the wide variety of the types of human errors, and the number of unique types of human errors, which appeared almost impossible to anticipate. Nevertheless, a common denominator identified was the fact that humans take actions based on their own mental model of how the system behaves, and very often their understanding of the system is wrong. These human errors occur during operation of the system, but they also occur during design and installation. Standardization, automation, and simplification are required to overcome these problems.

Survey respondents showed a lack of awareness regarding the dramatic reductions in harmonics created by recent generations of IT equipment. This subject is discussed in more detail in APC White Paper #26: "Hazards of Harmonics and Neutral Overloads".

Manageability Challenges		
Challenge	**Underlying problems**	**Power System Requirements**
Management of power at the outlet level	Unauthorized use of unused outlet receptacles creates unexpected overload conditions. Some IT equipment requires power-cycling to maximize performance or to reset from hung-up conditions. Powering down certain loads according to a schedule for security or energy conservation is a manual and tedious process.	Ability to control power at the outlet level, along with pre-engineered and easy to use tools to monitor and control large numbers of outlets.
Monitor power attributes at the rack level	Difficulty in determining racks that have high thermal loads, and racks that are near overload. Difficulty in associating branch circuit loads with racks due to constant reconfiguration. For dual path systems, difficulty in determining whether remaining circuits will overload when one path goes down.	Graphical user interfaces and automatic notification which report, manage, and notify based on parameters at the rack level.
Provide predictive failure analysis	Most power components fail or trip unexpectedly. No advance warning is provided that could allow corrective actions that might prevent load loss.	Instrument the power system in a way that provides advance warning of component failures. In the case of consumable or finite-life items, automatically notify regarding remaining expected life and replacement intervals.

The manageability solution requirements are extremely expensive to design, install, and test in uniquely engineered systems. These challenges clearly suggest the need for pre-engineered, pre-tested, and standardized management tools.

Survey respondents showed a lack of awareness regarding the time-varying power consumption of the newest generation of IT equipment. Therefore managing this issue did not emerge as a challenge. Nevertheless, this issue is expected to emerge as a key manageability challenge in the near future and is discussed in detail in APC White Paper #43: "Dynamic Power Variations in Data Centers and Network Rooms".

Serviceability Challenges		
Challenge	**Underlying problems**	**Power System Requirements**
Decrease Mean-Time-To-Recover (includes repair time plus technician arrival, diagnosis, and parts arrival times)	Spare parts are not readily available. Large systems that require complex disassembly process to diagnose and to repair.	Modular systems using standardized spare parts that are inventoried on-site or locally. Simple repair procedures that do not require complex disassembly.
Simplify the complexity of the system	Systems are so complex that service technicians and in-house maintenance staff make errors and drop loads when operating and maintaining the system. Status of the system cannot be easily determined or communicated during a crisis. Third party control systems are complex and unique and are never thoroughly tested, resulting in unexpected behavior during fault conditions	Standardized systems with standardized switchgear and standardized nomenclature. Pre-engineered and pre-tested control systems that don't take a lot of time to set up.
Eliminate hot work	The need to frequently change branch circuits, combined with the need to keep loads running 7x24, creates the need to re-wire circuits on live panel boards. This creates the opportunity for many types of human-error failures, and a serious health hazard.	System should adapt to changing voltage, power, and outlet requirements without the need for re-wiring on live panel boards.
Minimize vendor interfaces	Power systems often involve 10 or more vendors and it becomes difficult for in-house and even vendor personnel to determine which vendor is responsible for a problem, leading to the wasting of time and money.	Pre-integrated and pre-manufactured systems where it is clear who is responsible for a problem.
Learn from past problems and share learning across systems	Uniquely engineered systems where learning on one system cannot be transferred to another. No clear way that solutions for one customer's problem are communicated to other similar customers	Pre-engineered standardized systems where learning is shared through manufacturer notifications and automatic upgrade procedures

The last challenge involving learning from past problems, was expressed by some respondents as an availability issue, and by others as a service issue. Therefore it appears in both tables.

Power Systems for Mission Critical Installations

To satisfy the mission critical installation powering challenges identified in this survey, there are a number of changes required from current design practice. Many of these changes will require changes in the technology and design of power equipment, and how it is specified. Integration of the components of the power subsystem must move away from the current practice of unique system designs, and toward pre-engineered and even pre-manufactured solutions. Such solutions would ideally be modular and standardized, expandable at will, and would ship complete but in parts that would rapidly plug together on site. Standardization will facilitate the learning process. By spreading the cost of developing high performance management systems across large numbers of standardized installations, advanced power management would be affordable to all customers.

Conclusions

A systematic analysis of customer problems relating to data center and network room power systems provides a clear statement of direction for next generation mission critical installations. The most pressing problems that are not solved by current design practices and equipment have the common theme of the inability of the data center to adapt to change. Mission critical installation power systems must be more adaptable to changing requirements, in order to improve both availability and cost effectiveness.

In many industries, a maturity level is reached where new advances in reliability, cycle time, and cost require standardization, pre-engineering, and modularization. Designers of mission critical installations, designers of the power equipment used in them, and owners should consider whether this point has been reached. The results of the survey in this paper suggest the need for a new generation of adaptable power systems for mission critical installations.

References

1) FIPS PUB 94 “Guideline for Computer Power for ADP Installations”; National Technical Information Service