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Prescriptive and Predictive Power Management Strategies for High-Density Cabinets

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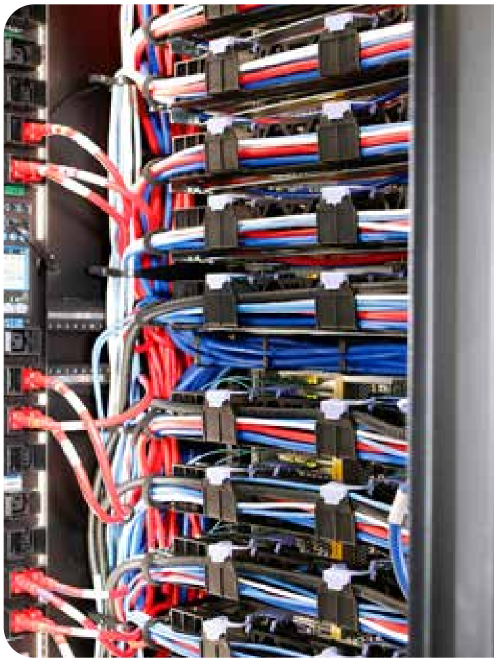
Data center equipment is growing more dense and power-hungry as multi-core CPUs and graphics processing units proliferate. This is creating challenges for data center managers to optimize power consumption to contain costs and meet sustainability goals without creating stranded capacity or overheated equipment.



Power consumption accounts for up to 80%[1] of a typical data center's operating costs. Prescriptive and predictive power management are becoming essential tools for achieving power efficiency and balanced power distribution while ensuring that power is always available for computing infrastructure.

The cost of downtime has been skyrocketing. Uptime Institute reported[2] that over 60% of failures in 2022 result in at least $100,000 in total losses, up from just 39% in 2019. The share of outages that cost upwards of $1 million increased from 11% to 15% over the same period. Predictive management helps avoid downtime by anticipating changes in demand, allocating capacity accordingly and conducting preventive maintenance without outages.

Smart power distribution units (PDUs) and uninterruptible power supplies (UPSes), combined with data center infrastructure management (DCIM) software, gives operators unprecedented visibility into power use, as well as the tools to forecast future needs.

Server Density is Growing

Surging power demands are being driven by increasingly dense servers. Uptime Institute estimates that the average server density per rack more than tripled between 2011 and 2020. Today, some racks now draw as much as 16 kilowatts of power. New demands for the high-performance computing needed to train artificial intelligence models may soon push that figure beyond 50 kilowatts.

High-density cabinets are one solution for managing this rapid growth. These enhance power and space efficiency by accommodating a larger number of servers, networking devices, and other IT equipment in the same space as a standard cabinet.

High-density cabinets are optimized for maximizing computing power within a confined area while maintaining efficient cooling, power distribution, and cable management. They help data center operators achieve higher computational capacity and performance – without drastically increasing the physical footprint of the equipment. They also reduce the risk of downtime because of their advanced cooling systems, reduced cable clutter, built-in redundancy, and energy efficiency.

High-density cabinets provide numerous other benefits:

- Space and power efficiency are improved through the consolidation of a greater quantity of computing power into a standard-sized rack.
- Better cooling efficiency is possible with the use of cooling solutions that are tailored to the specific needs of the equipment such as hot-aisle/cold-aisle configurations, containment systems and targeted cooling to the chip level. This reduces the risk of overheating, which is one of the leading causes of equipment failure.
- Capex expenses are reduced as more computing power can be accommodated in the same space.

- Packing resources more tightly reduces the need for cabling, which improves airflow, reduces points of failure, and simplifies maintenance and troubleshooting.
- All of these factors reduce overall costs.
- Resource-intensive and latency-sensitive workloads can be processed more efficiently with densely packed components connected by high-speed backplanes.
- Operators can accommodate increasingly power-hungry equipment without the need for new cabinets, thereby future-proofing existing infrastructure.
- Organizational agility is improved through faster provisioning of resources and lower time-to-market for new services.

While high-density cabinets offer numerous benefits, they also present challenges in the areas of power and heat management. Power imbalances inside the rack create the risk of overloaded circuits, localized hotspots, power inefficiency, uneven equipment wear and tear, scalability limits, and management overhead since identifying and correcting power imbalances can be challenging. An unbalanced input phase can create stranded - or unused - capacity in the data center as well as power quality issues such as harmonic distortion, which has a variety of upstream consequences. Careful planning is needed to ensure stability.

Intelligent PDUs Deliver Unprecedented Flexibility

PDUs manage and distribute electrical power to equipment, such as servers, networking devices, and storage systems. Unlike the basic power strips that are common in homes and offices, intelligent PDUs greatly enhance power monitoring and control. Remote monitoring and management of power consumption, voltage, current, and other electrical parameters help data center administrators track usage trends and identify potential issues before they escalate while also reducing energy consumption. Logging and reporting enable accountability through chargebacks and provides information on power hogs as well as ghost servers that may be candidates for consolidation.

Here are some key features of intelligent PDUs to look for:

- Monitoring of current draw on branch circuits ensures that the finite ampere capacities of the circuits are not exceeded, thus improving availability.
- Monitoring of power draws across all phases supports phase balancing that allows for the optimal use of power and minimizes power quality issues with upstream infrastructure.
- Outlet-level monitoring and control permits administrators to monitor the power usage of individual devices or equipment connected to specific outlets on the PDU.
- Remote power switching enables administrators to turn outlets on or off without requiring a physical presence in the data center. This enables “lights out” operation and permits 24x7 operations without the need for continuous on-premises staff.
- The ability to turn power individual outlets on and off remotely reduces the risk of overloads and minimizes the mean time to repair of IT equipment.
- Many intelligent PDUs provide real-time data on power consumption to help organizations automatically balance power allocation, identify energy-wasters, and improve overall energy efficiency.
- Integrated environmental monitoring of hot spots, which helps administrators take quick action to optimize the use of cooling resources.

- Alerts and notifications can be set based on predefined thresholds, enabling administrators to take timely action.
- Logging and reporting of historical power usage data enables predictive power management based on observed trends over time. This data can be used for capacity planning, identifying potential overloads, and optimizing power distribution.
- Many intelligent PDUs can also be integrated with DCIM software to provide a more complete view of the data center environment.
- Some even provide security features like user authentication and access control to prevent unauthorized changes to power settings. This feature is particularly useful in scenarios in which many people may have access to server equipment.

PDU technology is also constantly evolving. For example, circuit breaker-level alerts in today's PDUs notify administrators when a circuit breaker trips so that it can quickly be reset or the problem diagnosed. Switchable PDUs allow for individual outlets or groups of outlets to be turned on or off in a defined order to prevent voltage fluctuations that can shorten equipment lifespans.

Peace of Mind with Prescriptive Power Management
To optimize power consumption, reduce waste, curb emissions, and improve efficiency, data center managers are increasingly adopting prescriptive power management. This proactive discipline involves not only monitoring and analyzing power usage patterns, but also prescribing automated actions that achieve desired power-related outcomes.

Prescriptive power management is particularly relevant in today's sustainability-oriented business climate, which puts a premium on reducing energy use. The practice also helps with load-balancing by using data from intelligent devices to enable administrators to constantly monitor for areas of under- or over-utilization.

Here are some of the key elements of prescriptive power management:

Data collection and analysis uses sensors, meters, and monitoring systems to gather data about such factors as power consumption patterns, outages, battery health, load analysis, and maintenance.

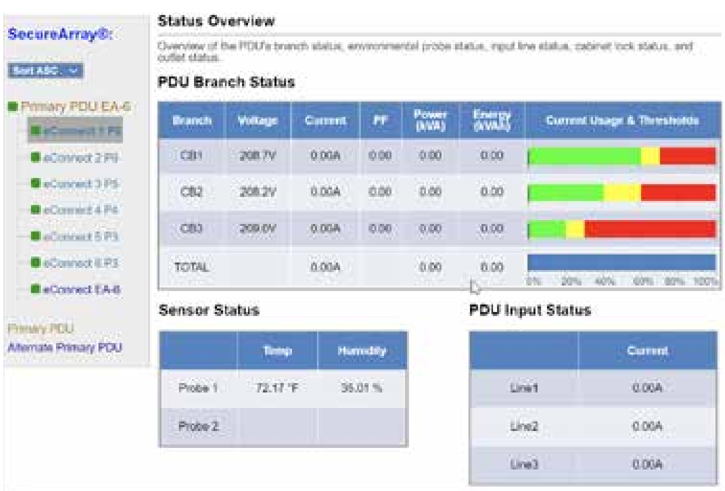
Data logging constantly gathers information about variables such as voltage, UPS capacity, frequency, temperature, and alarms to enable automated controls to be applied and allow operators to better plan for future needs.

Automated controls adjust power consumption, load, and resource allocation in real time based on demand and available resources.

Recommended optimization strategies provide advice that considers factors like performance requirements, cost considerations, and environmental sustainability goals.

Continuous improvement adjusts power management practices based on ongoing monitoring, analysis, and adjustment of historical power levels and results of management tactics.

By taking a prescriptive approach to managing power, organizations can reduce their environmental impact, lower operational costs, and enhance the reliability of their systems by preventing power-related issues.



Predictive Power Management

This discipline builds upon prescriptive power management by using analytics, machine learning, and other data-driven techniques to forecast and optimize future power consumption. Historical and real-time data from intelligent rack PDUs, remote power panels, and UPS systems is leveraged to predict future power usage patterns and enable proactive planning and equipment maintenance.

The goal of predictive power management is to balance power availability, cost considerations, and environmental concerns to optimize energy consumption and reduce waste. Historical data can show maximum, minimum, and average power consumption information that can be used for future capacity trending. It also provides information that helps to determine power consumption during peak and non-peak hours.

Predictive analytics is a forecasting technique that uses statistical algorithms to forecast future power usage patterns based on historical data and external factors, such as weather and costs. By analyzing historical consumption data, analysts can use DCIM software to extrapolate future needs to that extra capacity can be allocated or new buildouts made to support growth. This enables proactive planning for peak usage periods and helps avoid overloads. Predictive analytics is a standard feature of many DCIM tools or can be added with third-party extensions.

In addition to supporting balanced power availability, predictive power management also optimizes energy consumption and reduces waste. Organizations can make more informed decisions about expansion plans and avoid costly over-provisioning or underutilization.

Key components of predictive power management include data collection and analysis informed by historical power consumption patterns, environmental conditions, operational parameters, and external factors. Analytical algorithms are applied to identify trends, patterns and correlations that appear in historical data.

Predictive modeling forecasts future power consumption and balance requirements, factoring in historical data as well as variables like the time of day, season, environmental conditions, and equipment usage. Models typically simulate different scenarios to predict how changes in operations, load profiles and other factors may impact future power consumption. These are then used to develop strategies for optimizing power consumption proactively. Tactics may include adjusting operations schedules or allocating resources in a way that minimizes energy use during peak cost or high demand periods.

Real-time monitoring ingests streaming data feeds to continuously update predictions and adjust strategies as conditions change. Automated controls can adjust power states, lighting, cooling, and other power-reliant systems in response to real-time variables and expected changes in demand or availability. Monitoring such factors as the level of battery charge in the UPS or generator fuel levels allows operators to ensure that devices can reliably provide the power required to ride out short-term reductions or outages.

Monitoring the amperage and power usage of PDUs can give operators advance notice of impending issues such as overloads or imbalances and allow corrective actions to be taken before downtime occurs.

Granular reporting allows operators to see where stranded capacity is available, an insight that helps them maximize the distribution of power, cooling, and space to minimize the risk of disruption and also to potentially defer the need for capital expenditures.

All of this data can also be used for cost analyses that consider the full range of factors, such as utility tariffs, excess demand charges, and discounts. Environmental sustainability optimization calculations can be performed that empower operators to reduce a facility's carbon footprint through improved efficiency, use of alternative energy sources, and carbon credits. Finally, comprehensive reporting keeps senior managers, facility personnel, regulators, and other stakeholders up to date on the status of predictive power management efforts.

Power Management Best Practices

To realize the greatest benefits from predictive power management, data center operators should ensure that key equipment provides remote monitoring and control, configuration management, and proactive notifications.

Intelligent devices should be able to integrate seamlessly with other data center infrastructure components, such as power and cooling systems, to provide administrators with the most comprehensive view of all factors that affect power usage. Environmental monitoring systems that track temperature, humidity, differential pressure, air velocity and the presence of CO_2 should be factored into the equation.

DCIM is a critical part of both prescriptive and predictive power management. It provides administrators with the tools required to enhance operational efficiency and reduce costs through better asset management, capacity planning, energy management, environmental monitoring and integration with building management and IT service management tools. DCIM provides an integration and control point for all data about the health and efficiency of data center equipment.

There are four critical success factors in prescriptive and predictive power management:

Usability - The solution should be capable of being easily configured at a large scale without requiring time-consuming efforts to address each component individually. The user interface should be simple and support interaction via a web browser.

Manageability - The solution should be able to provide snapshot status updates on demand and allow operators to set critical thresholds and generate notifications and alerts when those thresholds are exceeded Logging capabilities support troubleshooting and auditing.

Integrability - Hardware elements should support the most common communications standards such as the Simple Network Management Protocol and messaging with MODBUS or BACnet. Application program interfaces should be provided to ensure that customers can integrate with the management and forecasting tools of their choice.

Security - Enterprise-grade multifactor authentication, role-based access controls and support for industry-standard security certifications are a must. Data must be encrypted both in transit and at rest. Vendors should commit to providing regular patches and updates to protect against new security vulnerabilities. Enhanced protection measures include biometric identification, video surveillance, intrusion detection and prevention, vulnerability scans and incident response plans.

Conclusion

The power demand curve for data centers will continue to trend up and to the right for the foreseeable future. Most organizations now communicate with their constituents primarily through digital channels, making downtime a nearly existential threat. Data center operators are under more pressure than ever to deliver high service levels and peak performance.

Fortunately, data center power technology isn't standing still. Operators should keep their finger on the pulse of the power management field, strive to automate wherever possible, and apply predictive analytics and emerging AI-driven controls to keep their facilities current with the latest innovations. Increasingly, they must also do so within the context of demands for more sustainable energy management practices. Those that succeed will be well-prepared to support the digital transformations that will create tomorrow's leading businesses.

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