Powering the Future:

Revolutionizing Data Center Design for Maximum Agility and Innovation

A NEW FRONTIER FOR THE DATA CENTER: THE IMPACT OF AI, ML, AND IOT ON POWER DISTRIBUTION

Artificial Intelligence (AI), Machine Learning (ML), Big Data, cloud computing, and the Internet of Things (IoT) – everywhere you turn, the data center industry is actively talking about how the applications that depend on these technologies will impact it today and beyond.

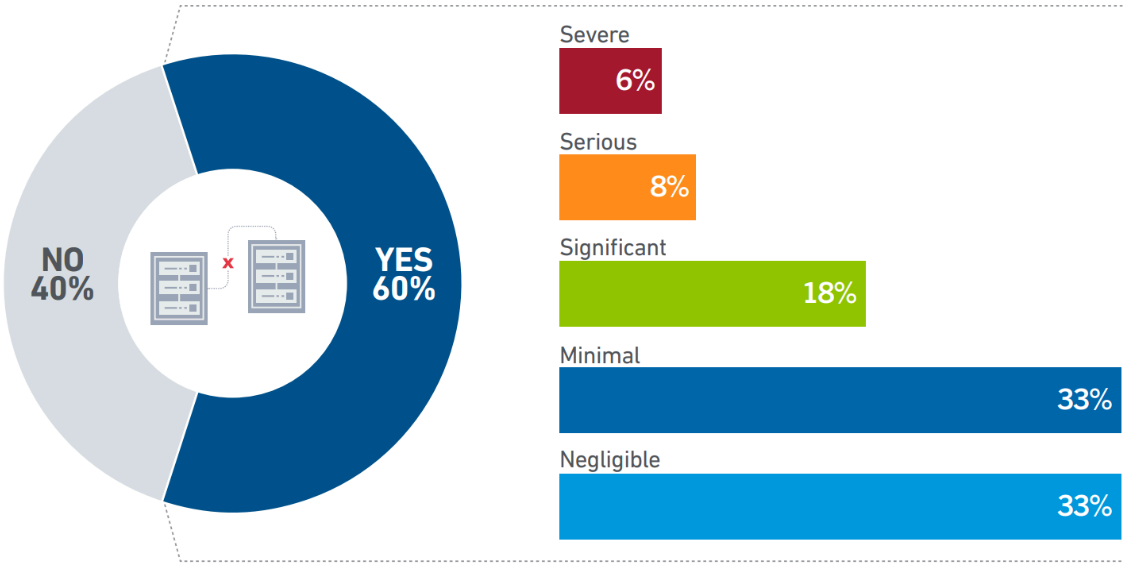
For this digital future to fully come to fruition, data centers must plan how to increase power densities by transforming their existing facilities and/or outfitting new ones for higher-density deployments, optimized efficiency, elevated reliability and resiliency, and enhanced sustainability.

From hyperscale facilities to edge data centers to any other area where mission-critical IT infrastructure is placed, the need for more efficient and high-density operations has never been more critical. That said, everything about the data centers of the future comes back to the power equation where power quality and power distribution make up the bedrock upon which the entire digital future rests. Comprehensively addressing these vital power requirements can set up forward-thinking data centers to support the digital innovations end users are increasingly adopting.

This whitepaper delves into the heart of this challenge, giving data centers a guidebook to the rack-based power quality and power distribution tools they need to support evolving high-density power requirements. As the demand for data center evolution intensifies, it becomes clear that visionary yet user-friendly, adaptable and flexible solutions are needed to ensure data centers thrive in the ever-progressing digital environment.

MANAGING UPTIME AND EFFICIENCY REQUIREMENTS STARTS WITH POWER QUALITY

Data centers are an “always on” business where uptime assurance is of utmost importance. Unfortunately, downtime is an issue that continues to plague the majority of data centers. According to a 2023 Uptime Institute survey, 60% of data center operators said they had an outage in the past three years. Among all the significant outages, on-site power problems were the most prominent cause. Even though power event diagnosis and power restoration can be quick, the same cannot be said for the time it can take to restart IT systems and re-synchronize databases. If equipment is damaged, data centers can find themselves operating outside their SLAs pending the installation of replacements.



(All figures rounded)

UPTIME INSTITUTE GLOBAL SURVEY OF IT AND DATA CENTER MANAGERS 2022

uptime INTELLIGENCE

While many data centers, per the Uptime Institute, point to UPS failures as the single biggest cause of power-related outages, this perspective is limited. The fundamental role of a UPS is to provide backup battery power in case of a power outage. There are other power considerations beyond grid or UPS failures that, if mishandled, can result in equipment damage and data center downtime. Because of this, data centers must pay attention to power quality throughout the power chain, especially at the rack and cabinet.

Data Center Design Challenge:
Understanding the Impact of Power Quality

Power quality is simply a means of expressing the stability of a power source and its ability to deliver ideal waveforms that stay within the specified range to equipment in the data center, enabling the infrastructure to run properly. Due to their nature, however, data center hardware introduces power quality problems into daily operations.

Though not all-encompassing, here is a snapshot of the types of data center equipment with the latent ability to cause problems to the voltage waveform:

- Non-linear switch mode power supplies used for servers, switches and storage systems.
- Variable frequency drive (VFD) fan motors found in HVAC systems.
- Pumps used to move liquids found in cooling systems, whether D2C, RDHx etc.
- Lighting ballasts.
- Rectifiers, whether on the input to UPS systems, or used as a common “power shelf” feeding DC power to a busbar in the rack.
- UPS inverters that turn DC power back into AC.
- DC-to-DC converters that exhibit AC waveforms superimposed on the DC output (AC ripple).

Deviations from the ideal power waveform take many forms. Here is a snapshot of just some of the most common ones:

- Harmonic distortion: This electrical noise can cause overheating of IT equipment, leading to damage and premature failure. Harmonic distortion can also cause interference with data transmission, leading to errors and diminished network performance.
- Voltage sags and dips: These short-term reductions in voltage levels can cause IT equipment to shut down or reboot, leading to data loss or system crashes.
- Transients: These sudden, brief voltage spikes and other short-term power events can damage IT equipment or cause it to malfunction.
- Interruptions: Complete loss of supply voltage categorized as instantaneous, momentary, temporary, or sustained occurrences, leading to data loss or system crashes.
- Frequency variations: These changes in the frequency of the AC power supply can cause IT equipment to malfunction or shut down.
- Voltage swells: These short-term increases in voltage levels can cause IT equipment to malfunction or fail.

Power quality problems can result in a myriad of issues for data centers, from false circuit breaker tripping, equipment malfunctions, synchronization errors of UPSs and generators during transfers, reliability problems, downtime and increased energy costs. High-voltage distortion drives up transformer core losses, manifesting as higher energy and cooling costs and higher power usage effectiveness (PUE). With new High Performance Computing (HPC) equipment like AI clusters featuring advanced GPUS (i.e., NVIDIA® H100 and H200) beginning to be deployed, power quality monitoring (PQM) and the ability to proactively address power quality issues is paramount in ensuring uptime and efficiency.

Data Center Design Tip:

Improve Uptime & Efficiency with Granular PQM

While independent power quality monitors can be installed upstream in a data center to measure power quality being fed from the utility, power quality deviations can still be detected downstream. The best way to address these inherent downstream power quality challenges is to employ rack power management equipment that enables continuous PQM, including total harmonic distortion (THD) measurements, at the source where critical IT equipment is being powered. Deploying next-generation intelligent rack power distribution units (PDUs) with built-in PQM at the branch and device level can help reduce or eliminate the effects of harmonics, voltage dips and swells, and other power deviations on vital IT equipment, promoting uptime, reliability and efficiency. Offered under the Server Technology® brand as the PRO4X and the Raritan® brand as PX4, Legrand®'s new-generation intelligent rack PDUs are all-in-one PDU solutions that feature:

- Real-time visibility, reporting and alerting of power quality metrics and events, including THD and Circuit Breaker Trip Forensics with Waveform Capture.
- Revolutionary intelligence to address capacity planning, environmental optimization, failover planning, and troubleshooting.
- An industry-leading metering accuracy level of ±0.5%.
- Best-in-class flexibility to meet and anticipate future requirements.
- Easy data collection and export to examine energy utilization.
- Secure communication, by default, for all PDU data.

The PRO4X and PX4 PDU's range of options to accommodate higher density power demands (AI, etc.) include:

- Single-phase: 100V, 120V, 200V, 208V, 230V, 240V, 277V*
- Three-phase: 208V, 400V, 415V, and 480V AC Inputs (DC Inputs also available)*
- 16A to 100A input
- 10kAIC breakers
- Up to 54 Outlets
- 60°C (140°F) standard temperature rating
- 0 to 3048m; 0 to 10,000ft operating elevation

*Some input ranges may not be available on both brands. Please contact a Server Technology or Raritan power expert for more information.

Legrand's innovative design combines over 30 years of battle-tested engineering and intelligence with industry-proven hardware and software to deliver the best visibility, flexibility, density and security. Alongside other best-practice design elements, deploying next-generation intelligent rack PDUs is one of the most crucial steps a data center can take to ensure uptime while improving capacity planning, workload and environmental optimization and failover planning. Built to monitor power at the outlet/device and infeed, PRO4X and PX4 Rack PDUs capture the granular power quality data that data centers need to monitor rack-based power events and visualize disturbances that may distort the PDU's power quality. These new-generation rack PDUs provide this information in real time to help improve the efficiency of installations and lessen the need for manual interaction at the rack when a power event occurs.

For further information on Legrand's Server Technology and Raritan branded new-generation intelligent rack PDUs, visit Legrand's website here.

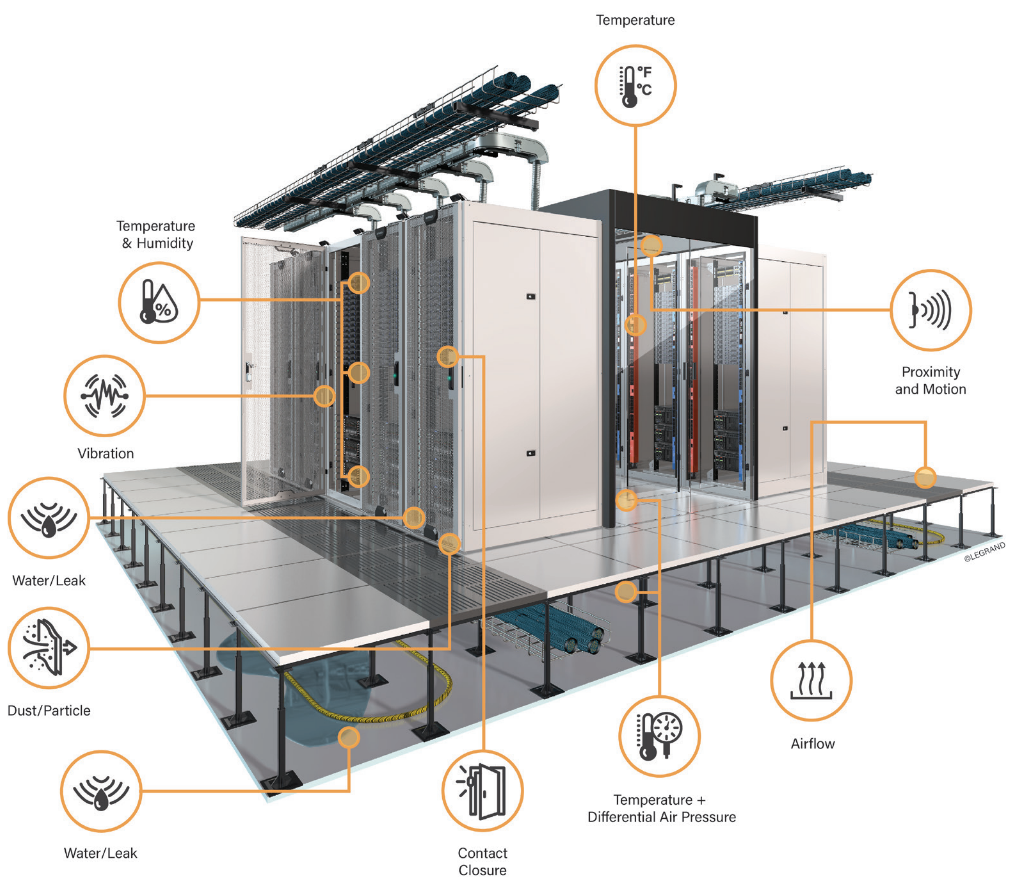
Data Center Design Tip: *Don't Forget About Environmental Monitoring at the Rack*

Performance demands on data center racks create new challenges within power and environmental infrastructures. High density in the data center is typically attained by increasing the computing power per square foot or rack. A high-density data center's faster, hotter chips, larger servers, cluster networks, storage, and rising densities push the limits of infrastructure and design. As data centers scale operations to meet high-density demands, power density naturally increases, driving up the heat generated by servers and other IT equipment, leading to environmental issues. To better monitor changing environmental demands in and around IT equipment, data centers need the right solutions to measure and manage environmental risk factors impacting operations' uptime, availability and cost.

Among the tools used in data centers, intelligent environmental sensors play a significant role in monitoring the "health status" of a data center. Sensors can provide alerts about potential problems that jeopardize the performance and life of IT assets. Today, more than ever, data centers rely on intelligent sensor tools to provide accurate insights into environmental health in and around IT equipment racks. These tools continue to advance and evolve to meet new data center challenges.

Deploying an environmental monitoring solution alongside, and often plug-and-play with, a rack power management solution – like Legrand's Server Technology PRO4X and Raritan PX4 Rack PDUs – will help to provide a complete picture of data center conditions at the rack, aisle and general white space. Environmental monitoring will help to reveal trends and alert operators to real-time risks and potential threats.

The idea is simple: you can't effectively manage what you can't monitor or measure. Data centers that provide a better-planned, more proactive environment have increased operational efficiency and maintain a higher service level. Achieving actionable, granular visibility into a data center and its operations requires operators to monitor critical environmental variables like cooling, temperature, humidity, water, dust/particles, vibration and more.



This is for illustration only and is not an actual deployment recommendation.

Popular Data Center Sensors

Legrand's SmartSensors™ are deployed as plug-and-play options with intelligent rack PDUs, and their advanced metering components provide highly accurate and valuable data. Furthermore, environmental data collected by SmartSensors can be instantly sent to DCIM or BMS software to see real-time environment data and trends over time – along with other infrastructure metrics, such as power capacity and power quality – on one dashboard. This information is critical to enabling a proactive environment for your data center operations, especially one prepared to meet the environmental challenges of higher-density data centers. For further information on Legrand's SmartSensors, visit Legrand's website here.

AI & POWER DISTRIBUTION DESIGN THROUGHOUT THE DATA CENTER

Of course, in addition to power quality, the underlying system that distributes power throughout data centers is also critical infrastructure. It must be reliable, flexible and adaptable to future needs.

Data Center Design Challenge:

Data centers are on track to become denser and much more power-hungry. A growing number of hyperscalers, cloud providers and other data center operators are continuing to deploy massive GPU clusters to meet their end user's AI and high-density needs. According to Precedence Research, the global AI market size will balloon to $2.6 trillion by 2032, up from $454 billion in 2022.

To deploy the critical IT infrastructure that will make an AI future possible (namely AI clusters composed of multiple H100 and future H200 GPUs), data centers must contend with many challenges, especially around electricity demand and power distribution.

In fact, the AI boom will likely cause global data center electricity demand to double. Per the International Energy Agency (IEA), the data center industry's total electricity consumption could reach more than 1,000 terawatt-hours (TWh) by 2026, up from 460 TWh in 2022. This growth would place the entire industry on the same level as the electricity consumption of Japan.

Within the data center, deployment of AI clusters will mean increased rack power densities of 20 kW and beyond, at scale. As of 2022, only 10% of data centers reported rack densities of 20-29 kW per rack. Only 7% handled rack densities of 30-39 kW and 3% at 40-49 kW per rack. To meet the needs of AI and other demanding HPC applications, data centers will incrementally, but increasingly, push beyond 20 kW a rack to ever higher densities. In the modern age, extremely high-density racks range from 40 kW to 125 kW. Some advanced data center end users are even demanding densities of 80 kW to 200 kW per rack today.

While the data center industry is still far from mass adoption of extremely high densities, pushing past older density barriers will require significant changes to power distribution technology above the PDU level. These include shifting away from:

- Traditional 120/208V distribution
- Small power distribution block sizes
- Standard 208V 3-phase 60/63A rack PDUs

Consequently, the ideal power distribution solution within the data center enables extreme high-density deployments, flexibility for ever-changing IT configurations in confined spaces, a lowered total cost of ownership compared to other power distribution methods and, of course, granular energy and power management.

***Data Center Design Tip:** Improve Agility and Scalability with Track Busway Technology*

Forecasts predict that the global AI market will increase from $454 billion in 2022 to $2.6 trillion by 2032. With that growth will come an even greater spike in data center energy usage. The International Energy Agency (IEA) believes the industry's total electricity consumption may double to over 1,000 terawatt-hours (TWh) by 2026 compared to 460 TWh in 2022.

As a result, rack power densities will expand correspondingly from today's high end of 20 kW to 40 kW and beyond. In extreme cases, data center operators may have to achieve densities of 80 kW to 200 kW per rack. Supporting these ever-higher-density racks will require power distribution systems that are reliable, flexible and able to adjust to future needs.

The optimal overhead power distribution solution for these increases is Starline's Track Busway. Revolutionary track busway technology is one of the most energy-efficient systems available today, eliminating the jungle of wires that obstructs airflow under the raised floor. Through this technology, data centers can avoid the headaches of reconfiguring their IT infrastructure to meet the demands of deploying AI clusters.

Flexibility

Starline's track busway products enable facility managers to easily expand, reconfigure or relocate operations. With rapid installation and a continuous access slot to power, Starline Plug-in Units can be added wherever power is needed and within a matter of minutes. As a result, there is no need to tie up valuable capital until expansions in the existing electrical distribution system are extremely urgent. With section lengths manufactured to custom specifications and overhead, wall-mount and rack mounting options available, this busway system reduces installation time and labor compared to busduct as well as pipe and wire products, and requires no routine maintenance. It also eliminates the need to call specialized electricians to perform complicated wiring work when additional server racks must be installed, or the existing layout reconfigured. Its sleek design, characteristic of other Starline Track Busway products, enables greater flexibility compared to larger, conventional busway solutions on the market today.

High-Density Support

Track busway combines technical reliability, extreme versatility and support for higher densities into one product, and is available in various sizes, from 40 to 1250 amps with 3-phase systems rated up to 600Vac or 600Vdc.

Reliability

Thanks to its continuous access slot, power can be tapped at any location. This means that the solution's configurable plug-in units can be disconnected and connected without de-energizing the busway, making it the perfect solution to supply power around the clock. Using the track busway in tandem with any of Starline's revenue-grade Critical Power Monitor (CPM) products provides real-time, granular voltage, current and power data with configurable alarms. Starline Track Busway plug-in units ensure uninterrupted power supply for data centers by using a compression-fit method and can be secured to minimize accidental power disruptions.

Lower Total Cost of Ownership

With a litany of features that make Starline Track Busway easy to implement, adapt and operate, it should come as no surprise that the total cost of ownership is lower than traditional underfloor power distribution systems. Material costs are on par with conduit and wire material costs and far lower than larger, conventional busway products. However, dramatically reduced installation and maintenance time and costs is where the bulk of savings is found. Starline Track Busway enables data center operators to avoid panel boards, long runs of conduit and wire, and high installation and maintenance costs.

To learn more about the Starline Series-S Track Busway, visit the product's website here.

CONCLUSION

The demands of the digital future due to the explosive growth of AI, ML, IoT and other compute-heavy services will place an ever-increasing load on the modern data center's existing power distribution systems, even down to the rack PDUs powering IT equipment. Higher density requirements and ever-higher electrical consumption indicate a greater need for granular, revenue-grade power monitoring down to the rack and PDU outlet level. They also point to the need for intelligent power distribution and power monitoring solutions that offer increased granularity and accuracy. Legrand's PRO4X and PX4 next-generation intelligent Rack PDUs do this all-in-one at the rack level, offering industry-leading accuracy and granularity while inherently supporting high-density deployments, especially higher power densities. Legrand's Starline Track Busway also supports high-density deployments because of its flexibility, adaptability and IP54 rating. Paired with the Starline CPM, it also provides revenue-grade metering that will become increasingly important as data center demand for electricity rises. Using products like Legrand's in concert with one another will help data centers adapt their existing facilities and/or outfit new ones to meet the rising power demands that AI, ML, and IoT require.

CITED SOURCES:

- https://uptimeinstitute.com/resources/research-and-reports/annual-outage-analysis-2023
- https://www.legrand.us/critical-power-and-infrastructure/rack-power-distribution
- https://www.legrand.us/critical-power-and-infrastructure/rack-management/environmental-sensors
- https://www.precedenceresearch.com/artificial-intelligence-market
- https://uptimeinstitute.com/resources/research-and-reports/five-data-center-predictions-for-2024
- https://datacentremagazine.com/data-centres/ai-boom-will-cause-data-centre-electricity-demand-to-double
- https://www.sdxcentral.com/articles/analysis/data-center-rack-density-how-high-can-it-go/2023/09/
- https://starlinepower.com/busway/

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