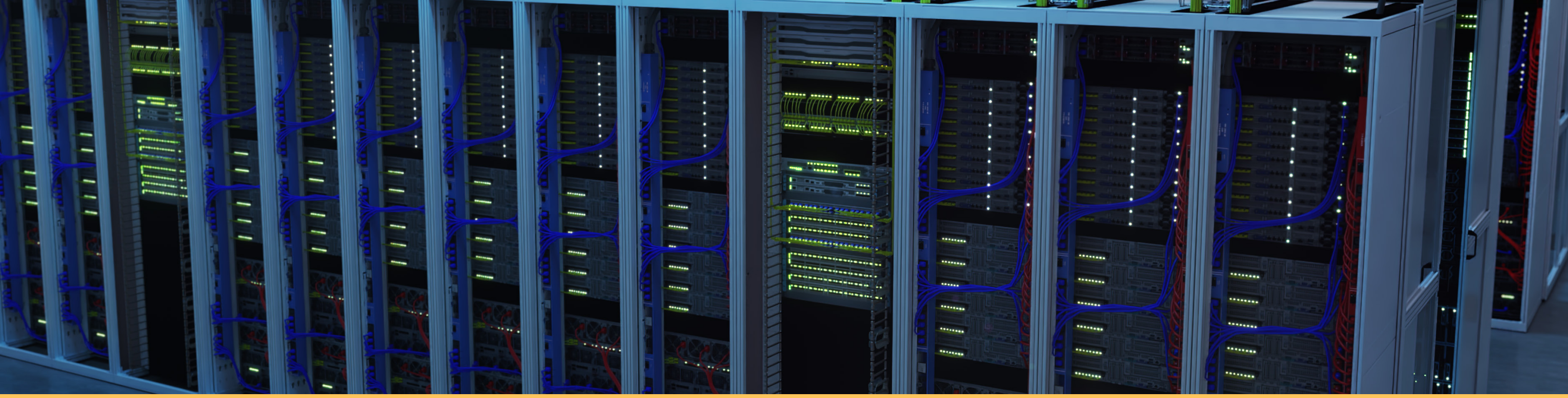
WHITE PAPER

Significant Advancements in Rack PDU Power Quality Monitoring and Metrics Greatly Improve Uptime



EXECUTIVE SUMMARY

Rising power demands and the global initiative of reducing carbon footprints make measuring all aspects of a data center's rack power critical in supplying highly available, reliable power. Beyond the actual power the rack uses, power quality measurement details can troubleshoot sources of power issues such as distortions and variations. These measurements can increase energy efficiencies, improve availability, and manage the existing capacity of the entire data center. Because data centers require an extremely high degree of electrical availability and reliability, an awareness of power quality issues and how to address them—down to the rack or device level—is necessary to protect from downtime's prohibitive costs. As rack power quality patterns become recognizable over time, a long-term monitoring strategy can help find what processes are leading to a critical situation to help prevent similar cases.

Trending data from the Uptime Institute's research shows that data center outages cost more, and the stakes are only rising. Electrical reliability and rack-level power quality are becoming a critical part of solving a data center's downtime prevention equation. However, many data centers are still risking their bottom lines because they lack advanced intelligent rack power distribution unit (PDU) based metering for monitoring and addressing power quality issues at the rack (and device) level.

Many data centers face challenges in obtaining accurate power quality data at the rack level due to insufficient information from PDUs. This lack of detail can have adverse effects on both performance and safety, underscoring the need for a solution that delivers precise and comprehensive power quality data. To make matters worse, this instrumentation trend often requires data centers to install separate power monitoring devices, conduct manual monitoring, and enlist the help of outside experts to solve power quality difficulties. With power quality issues still a leading cause of data center outages, there must be a better way to address rack-level power quality and monitoring at the IT load.

This paper addresses the advantage of using next-generation intelligent rack PDUs with built-in advanced power quality metrics and diagnostic tools that provide the granular level of real-time power quality measurement data needed for rack power optimization to ensure uptime.

THE LAST MILE OF THE POWER CHAIN

The rack PDU is the final endpoint of an elaborate, typically redundant, power chain that powers IT equipment in a data center. Because most power delivered to a data center from the utility is consumed by IT devices plugged into rack PDUs, it is typically where a fluctuation in the quality of power at the power's load is realized. Because of this, data centers are increasingly viewing rack PDUs as a network of critical devices that can significantly affect their overall efficiency and effectiveness, and not merely as a collection of power outlets for IT equipment.

In most data centers, the IT load typically uses 40 percent of the power load *(see Figure 1)*. The types of loads, and the quality of the devices being powered, vary within the cabinet and in a data center. Data centers use different power chain designs to manage power efficiency to reduce the risk of outages. These designs can range from simple to complex depending on the desired level of fault tolerance and facility rating (as defined by the Uptime Institute).[3] The fault tolerance level is considered by many as the primary measurement of evaluating electrical availability to IT equipment and cooling systems, as well as other miscellaneous power loads such as lighting, security, and other building support functions. While measurement and monitoring tools are available along the power chain to identify power quality and energy efficiency issues, at the rack, next-generation intelligent rack PDUs are now designed with built-in advanced power quality metrics and diagnostic tools at both the inlet and outlets to ensure the desired fault tolerance level is continuously monitored and reached.

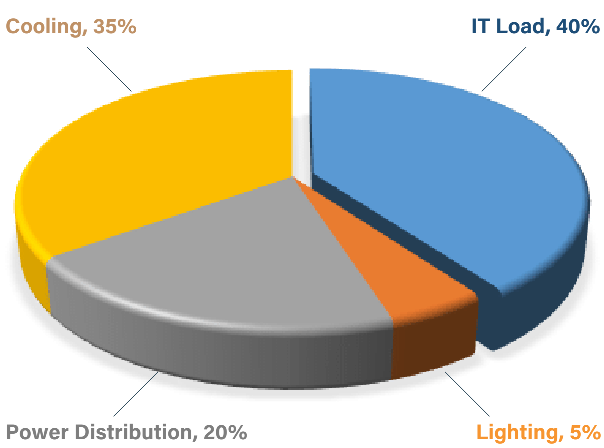


Figure 1: Typical Data Center Power Consumption[1]

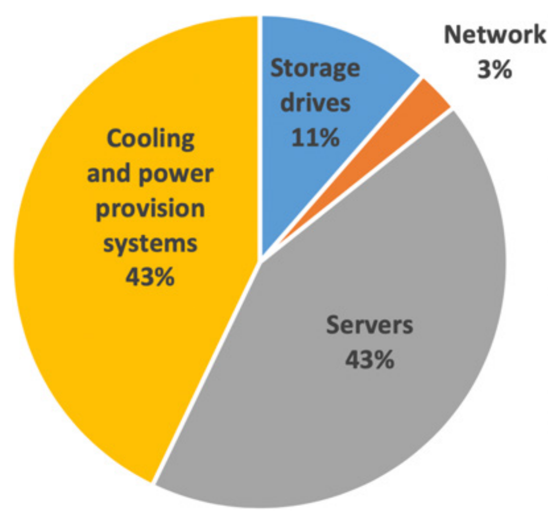


Figure 2: Typical Data Center Electricity Use by End Use[2]

WHY IS POWER QUALITY AT THE RACK IMPORTANT?

Data center racks can accommodate different types of devices, such as servers, storage devices, and network equipment. Servers can vary in size, from large blades to small 1RU "pizza box" servers. In addition, the infrastructure or spaces will be a complex mix of purpose-built data centers and co-location sites to retrofit storage closets in retail or office environments. Accordingly, the reliability and overall quality of the power being supplied will vary greatly.

One thing that ties all these spaces and devices together is the switch-mode power supply (a power supply that incorporates a switching regulator to convert electrical power efficiently) IT devices used. With the introduction of these switch-mode power supplies, there have been standards defined related to their operation, such as the CBEMA Curve by the Computer and Business Equipment Manufacturers Association (CBEMA)—since reorganized and renamed the Information Technology Industry Council (ITIC). The CBEMA Curve originated in the 1970s and was widely referenced in the IT industry for several decades. While it was updated and superseded in 2000 by the ITIC Curve, the curve provides universal power supply design requirements like the holdup time to ensure uptime when power is lost.[4] While these requirements are helpful, they are still not immune to surges, spikes, and other electrical disturbances, such as harmonic distortion and related noise. The drive for data center energy efficiency has significantly improved the electrical characteristics of an IT equipment's power supply. While power supplies have improved energy efficiency and power factor, they can still introduce harmonics into the power distribution system.

The US Energy Star® program for data center equipment has detailed this in its specifications. However, while these specifications apply to the latest Energy Star power supply requirements, many devices are not rated Energy Star. They may have a greater total harmonic distortion and lower power factor than one might think. This is especially true for non-major server vendors, older servers, and devices that are not servers.[5]

Noting that power factor decreases at lower loads, for most data centers that use devices with dual-corded redundant power supplies, the normal load on each power supply is less than optimal loading resulting in a lower power factor and loss of efficiency. Some server designs concentrate the full load on a single power supply and only rely on the second power supply to support the load if needed.

WHAT CRITICAL POWER METRICS CAN BE MONITORED AT THE RACK?

Because data centers now see rack PDUs as critical devices affecting their overall efficiency and effectiveness, it is essential to implement and use next-generation intelligent rack PDUs designed to monitor and report detailed real-time power quality measurements. For most data centers, intelligent rack PDUs are the best power monitoring solution to reduce costs, increase energy efficiencies, improve availability, and manage the existing capacity of the entire data center.

Legrand's® Raritan® and Server Technology® brands of intelligent rack PDUs are the first to include built-in advanced power quality metrics at the rack. Legrand's next-generation rack PDU models (the Server Technology PRO4X and the Raritan PX4 rack PDUs) include detailed power quality measurements both at the PDU inlet or, often called the PDU infeed, as well as at the PDU outlets or IT load *(see Table 1).*

Table 1: Raritan and Server Technology Rack PDU Infeed & Outlet (Device) Power Quality Metrics

Rack PDU Power Quality Metric	Measurement	Available at the PDU Infeed (Yes/No)	Available at the PDU Outlet (Yes/No)
Voltage, RMS	V_{RMS}	Y	Y
Voltage, Neutral	V_N	Y	N
Voltage, Harmonic Distortion	V_{THD}	Y	Y
Voltage, Dip & Swell	V_{DIP} V_{SWL}	Y	N
Current, RMS	A_{RMS}	Y	Y
Current, Neutral	A_N	Y	N
Current, Inrush	A_{INRUSH}	N	Y
Current, Harmonic Distortion	A_{THD}	Y	Y
Crest Factor	CF	Y	Y
Watts	W	Y	Y
Volt-Amps-Apparent Power	VA	Y	Y
Volt-Amps-Reactive Power	VAR	Y	Y
Power Factor, True	PF_{true}	Y	Y
Power Factor, Displacement	PF_{disp}	Y	Y
Power Factor, Distortion	PF_{dist}	Y	Y
Energy	kWh, kVA	Y	Y

Metrics with Y (yes) in the PDU Outlet column are only available on our rack PDUs equipped with outlet level monitoring.

To better understand where and why these rack-level power quality measurements are within the rack PDU itself, review the following electrical terms, referenced throughout this paper:

- **Current (Ampere or A):** the flow rate of electric charge; current measured in amperes.
- **Active Power (Watt or W):** the work done by an IT device and is the measurement by which power companies bill for use.
- **Reactive Power (VAR):** power flowing back and forth between the power company and electrical devices due to capacitance and inductance within the IT device. Reactive power does not perform useful work and is not billed by power companies.
- **Apparent Power (Volt-Ampere or VA):** the product of voltage multiplied by current. It is the sum of the active and reactive powers.
- **Power Factor (PF):** the ratio of Real Power to Apparent Power. A Power Factor of 100 percent indicates perfect power, while lower values indicate wasted power due to reactive power or harmonic distortion. Power companies may charge a surcharge if the power factor is below a threshold.
- **Power:** the rate of doing work, usually expressed in horsepower or watts.
- **Load:** the amount of amps used by devices. Amperes, or amps, are a standard measurement of electrical current for how much electricity is moving through a wire at a set time. The amp draw is calculated by the electrical requirements of the devices plugged in and is regulated by a circuit breaker or fuse.
- **Voltage (Volt or V):** a fixed value for a circuit that measures electrical potential.
- **Crest Factor (CF):** the ratio between the instantaneous peak current required by the load and the RMS current. A high crest factor can lead to overheating of power supply components.
- **Inrush Current:** is when server power supplies draw more current when first turned on.
- **Harmonic Distortion (THD):** measures how much of an electrical load is distorting the power provided by the utility. At the rack, harmonics are always present in current and voltage. Too much variation can accumulate and disrupt power quality, leading to increased electrical usage, power quality fluctuations, or overheated wires that can cause damage to IT equipment.

Power Monitoring Locations within the Rack PDU

Power metrics are measured and monitored at the PDU’s infeed and outlets or device level. Monitoring also simultaneously occurs at the PDU’s branch circuits to ensure uptime, especially if there is an overload or short related to the devices plugged into the PDU. Legrand’s Raritan and Server Technology intelligent rack PDUs offer different monitoring levels to fit an application’s needs. If an application does not need to monitor or measure at the outlet or device level, Legrand offers solutions that only measure at the PDU’s branch and infeed levels. Below, let’s review some measurement metrics and their location along the PDU.

Per Infeed Power Sensing

Monitoring at the PDU infeed enables the user to optimize capacity planning, available power, overhead planning, and identifying areas of stranded capacity.

Rack PDUs equipped with infeed power sensing technology can replace monitoring at the remote power panel (RPP) in a data center with higher accuracy and lower cost monitoring of each power circuit attached to a PDU. The RPP metering data can also be used as a tool and compared against the date and time-stamped PDU-based power quality metrics to help track down power quality problems at their source to prevent problems. Infeed power sensing enhances PDUs with accurate and complete power metrics. Expect the same quality and functionality of an intelligent PDU but with increased data to make more informed and critical decisions about the data center.

An infeed power sensing equipped rack PDU can:

- Monitor current, voltage, power, apparent power, crest factor, reactance, power factor, and accumulated energy.
- Configure alarms, thresholds, permissions, email alerts, security settings, communication settings, and SNMP traps.
- Quickly confirm the status of rack power and environmental conditions such as temperature and humidity.
- Share device-level power data with other systems through open APIs.

Branch Monitoring

Per the UL 60950-1 standard and the new 62368-1 standard, rack PDUs rated for more than 16 amps must supply an overcurrent protection device (OCPD) within the PDU. Typically, these are circuit breakers or fuses, with each type of OCPD having advantages and disadvantages. Each branch circuit must be protected at 20 amps per UL standards.

In a properly designed PDU, the number of branch circuits and their ratings relate directly to the power infeed coming into the PDU so that the PDU can deliver all the power to the load provided at its power infeed. The key is to make sure that at no point does the amount of current drawn exceed the rating of the OCPD, which would take down the branch circuit, the connected devices associated with that branch, and in some cases, the upstream breaker (which would take down the entire PDU). This situation is common when using circuit breakers and not comparing the trip curves of the PDU breakers with the upstream breakers located at the Remote Power Panel (RPP) or busway. Consider a coordination study of the OCPD and upstream breaker at the panel/busway to avoid future issues—helping identify and address potential problems before they escalate.

To ensure the branch circuit is not overloaded, the current load is measured at each branch and supplies both Low Alarm/Low Warning and High Alarm/High Warning user-set thresholds.

Per Outlet or Device Power Sensing

Monitoring power at the PDU's outlet or device level can give valuable insights into the quality of power at the rack and is becoming a more commonly used rack PDU feature. For example, monitoring outlets can help detect power supply issues where a decrease in power factor could indicate a power supply problem, but it may require further analysis to fully understand the issue. Another indicator, measurable at the inlet and outlets on specially equipped PDUs with per outlet power sensing, is to measure the crest factor. The crest factor is a measure of peak-to-average current and is an indicator of the presence of harmonic distortion if the value is above 1.41. If a power quality problem is still suspected, it's recommended to measure both the harmonic distortion for the current and voltage as well as the distortion power factor. The distortion power factor is a direct measurement of the inefficiency due to harmonic distortion. A distortion power factor of 0.95 indicates 95 percent of the power is being put to useful work and the remainder is wasted on producing harmonic distortion.

Outlet-level monitoring of multiple outlets can be related to a particular device or server. Device power information has a ton of value because it looks at the power consumption of a group of similar devices to decide which devices are doing valuable work and which are simply sitting idle and wasting power. This approach is often much more feasible than unplugging the network cable on a device and waiting for an angry user to contact IT support.

Multiple devices or servers can often relate to the power usage of a particular application or group within a data center. This information is also valuable if a data center has considered billing back to different departments for their power usage to reduce costs and drive efficiency. It's worth noting that many people want unlimited resources and power without considering the associated costs involved.

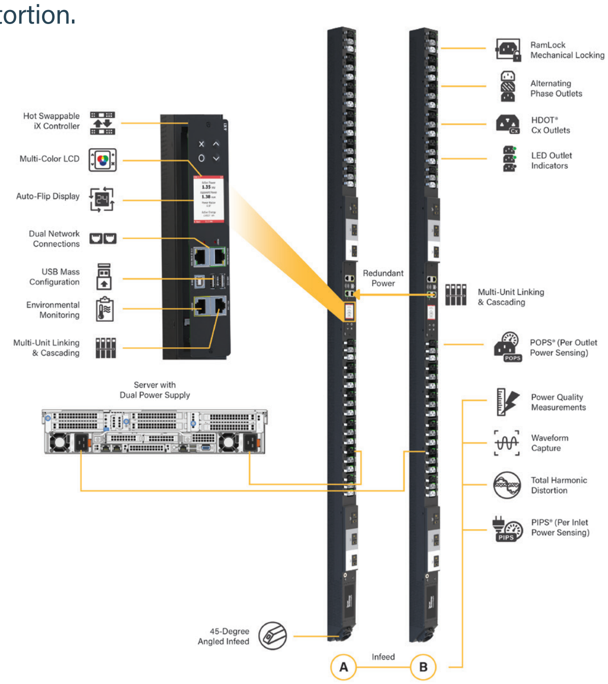


Figure 3: Server Technology PRO4X Rack PDU Equipment View (Not all features are highlighted)

WHAT VALUE DOES POWER QUALITY MONITORING PROVIDE?

Two crucial factors in supplying high-quality power are to decide if there are power quality issues and what type of power quality problem exists. Once that is determined, it becomes possible to derive a proper plan to mitigate those challenges. Without a rack PDU with the appropriate built-in power quality meters, data centers must install external meters to supply continuous power quality monitoring throughout the cabinet. A power quality meter should capture and view waveforms, detect disturbances like voltage sags and swells, measure harmonic power flow, and supply alarms when measurements are outside a set tolerance range.

In addition to identifying power quality problems, it is also essential to be aware that power quality can mean different things and have other consequences for different operations. For example, data centers housing sensitive electronics and IT equipment that cannot fail, regardless of the result, have small tolerances for deviations in power quality. These facilities are called upon to operate 24/7 and rely on high-quality power to keep the systems operating normally. Electronic equipment is more sensitive than ever to minor and transient variations in voltage. Furthermore, every minute of downtime carries a greater penalty than ever before. In short, the cost of downtime has increased dramatically, and so has the likelihood of failures caused by power quality problems *(see Figure 3 and Figure 4)*.

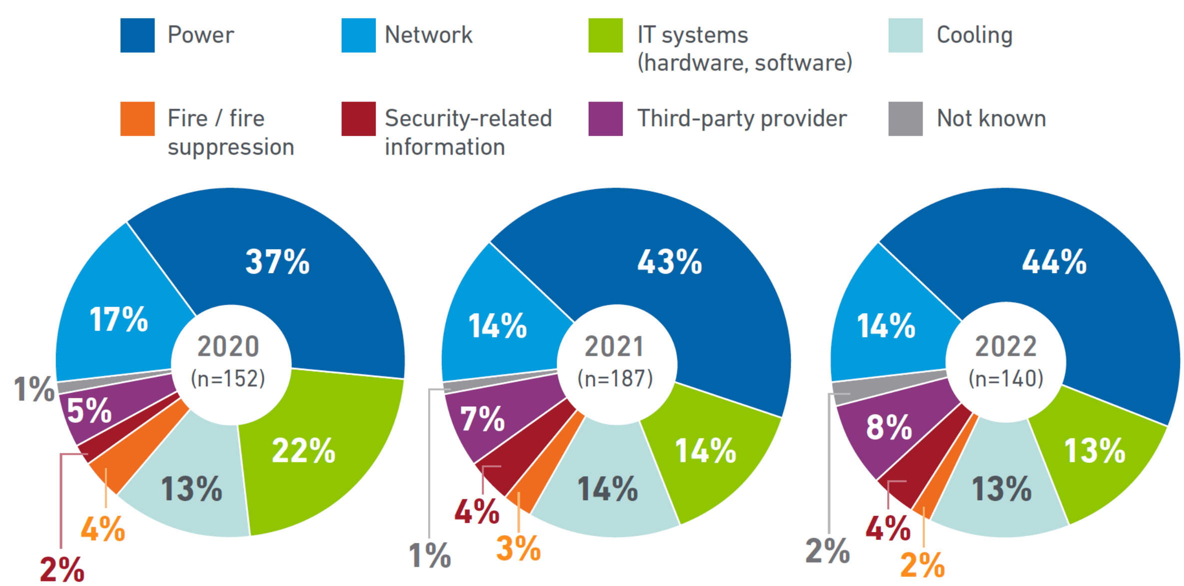


Figure 4: Uptime Institute's Primary Causes of IT and Data Center Outages[6]

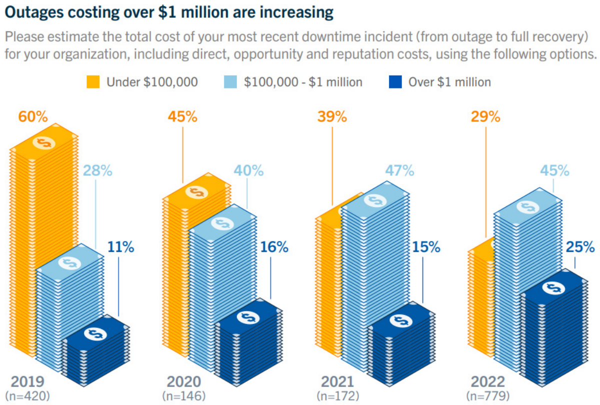


Figure 5: Uptime Institute's Cost of Data Center Outages[6]

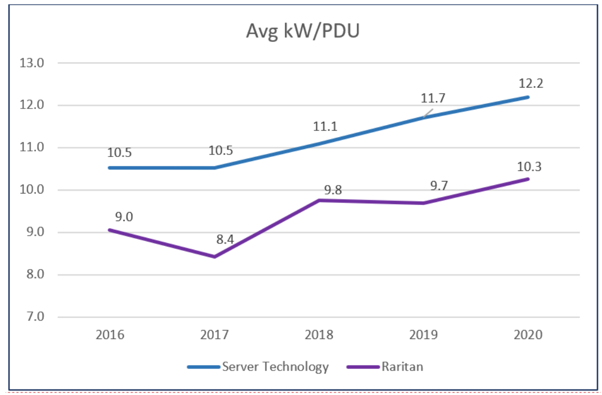


Figure 6: Power Densities are Increasing, this Chart Shows Server Technology and Raritan Rack PDUs per Average kW

The backbone of ensuring clean, uninterrupted power to IT equipment is the "double conversion" online UPS (Uninterruptible Power Supply). While this type of UPS isolates and mitigates most utility-side power problems, it cannot protect IT equipment from power issues, such as noise from harmonics generated downstream of the UPS output.

By their very nature, IT equipment Power Supply Units (PSU) are nonlinear loads that can also introduce harmonic distortion. In addition to the issues generated by the IT equipment power supply, other equipment, such as some supplemental high-density cooling systems (typically fan motors with variable frequency/speed controllers), are also powered by the UPS.

Average rack power requirements have risen from 10.5kW in 2016 to 11.7kW in 2019 and 12.02kW in 2021; it is not unusual to see racks wired to provide 17kVA or more than 57kVA *(see Figure 6).* Most data centers use 3-phase power distribution to deliver the needed kW to the rack and increase overall efficiency. Today, increased power densities are related to the number of devices and the overall kW needed within the cabinet. Though the power densities have not increased as much as predicted due to platinum-grade power supplies and system changes like virtualization and server consolidation, increased densities remain challenging within the data center space.

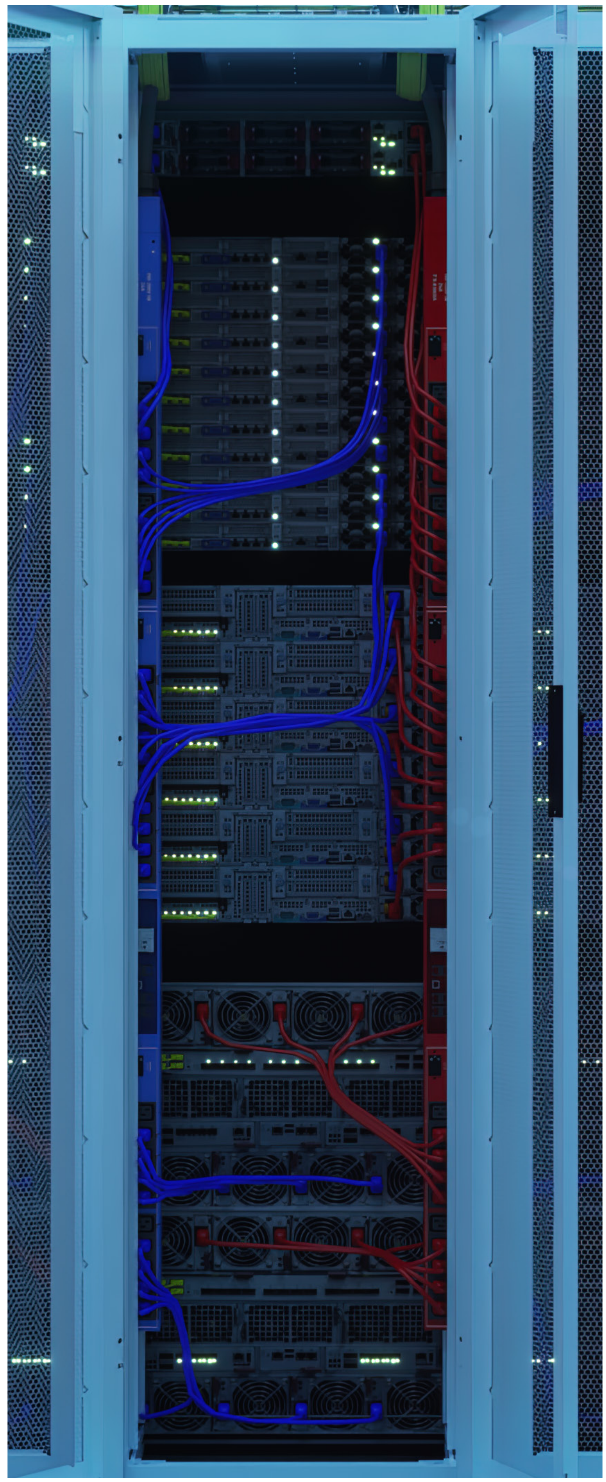
With kW continuing to rise, most power consumed within the data center is distributed as 3-phase power. Of course, most IT equipment power used in data centers at the device is single-phase power. In these applications, 3-phase power is brought into the PDU and distributed as single-phase circuits to the rack devices as either 120V, 208V, 230V, 240V, or 277 volts. Data centers commonly use 3-phase power distribution from remote panels or large PDUs. With newer 400/415V systems, the power is 3-phase and distributed to devices as single-phase 230/240V. This scenario is becoming more common in the US and is already widely used in other parts of the world. As in all cases, the IT equipment used has switched-mode power supplies, which, while power factor corrected, produce harmonic distortion and vary the power factor and crest factor concerning load conditions.

WHAT IS THE BEST WAY TO LOOK FOR POWER QUALITY ISSUES AT THE RACK?

How to Define an Advanced Power Meter

Built-in meters within the rack PDU provide continuous power quality monitoring, which ensures power quality issues are being resolved before they result in problems with reliability and uptime. These internal PDU meters supply many functions at once, including the following listed below:

- A high-quality PDU-based digital meter to measure power consumption, look for stranded capacity and provide information about the IT load when calculating parameters like PUE (Power Usage Effectiveness) *(see Table 1)*.
- Monitoring capabilities at both the PDU infeed to confirm power quality going to the devices and at the PDU's outlet/device level to decide potentially harmful power events.
- An alarm and notification system that allows SNMP traps, email alerts, or open API calls when conditions exceed established thresholds.
- Power metering advanced functionality to capture waveforms and other power quality information to support a complete analysis of the problem.
- Specific applications like data centers should meet specific UL/IEC standards that ensure accurate and valuable information.



The main benefit of built-in meters within the PDU lies in providing real-time information that can be used to predict and prevent power quality problems before they lead to equipment malfunction, overheating, or other issues. This information is not only offered in real-time, but it is also as highly accurate as a 0.5 class meter in ensuring high-quality and reliable metering metrics.

HOW POWER QUALITY CAN AFFECT AN IT NETWORK'S INTEGRITY AND PERFORMANCE

When data centers plan for a facility's electrical power, most focus on calculating the power consumed by IT equipment and facility operational resources. They generate an initial energy efficiency estimate but often overlook and underestimate power quality and the issues that may occur directly affecting uptime and reliability.

In a data center, there are various types of power quality issues that can occur along the power chain, including glitches, spikes, disturbances, flickers, blinks, and more. These issues can be identified and addressed by monitoring them closely, ensuring maximum efficiency and electrical safety for the data center. It's important to note that while these issues may show that "something" occurred, the IEEE[5] has classified them into specific categories, including:

- **Transients:** Spikes, other short-term events that raise the voltage and/or current.
- **Interruptions:** Complete loss of supply voltage categorized as instantaneous, momentary, temporary, or sustained.
- **Sags:** Reduced AC voltage duration of half-cycles to 1 second.
- **Undervoltage:** Reduced AC voltage of several seconds or longer (i.e., "brownout" of utility power).
- **Swell/Overvoltage:** Inverse of a sag, increased AC voltage.
- **Waveform Distortion:** Any imperfections of a sine wave: harmonic distortion, voltage or current clipping, or spiking.
- **Voltage Fluctuations:** Unstable random or repeated voltage changes: short or long term.
- **Frequency Variations:** Any change from the nominal frequency.

Power Factor

To ensure that the power draw of electronic devices does not have a significant cumulative effect on the power system, standards like International Electrotechnical Commission 61000-3-2[7] were established to set limits on power factor degradation and harmonic distortion introduced by power supplies. This standard forced computer vendors to transition from older switched-mode power supplies to power factor-corrected power supply technology in data centers with large amounts of nonlinear IT equipment.

Most switched-mode power supplies distort current and voltage waveforms, which cause high harmonics. The PFC (Power Factor Corrected) power supply aims to make the power factor as close to one (1) as possible, where the current waveform is proportional to the voltage waveform. The PFC uses filters and/or electronic switching elements to force the input alternating current to be sinusoidal with minimal distortion and in phase with the input voltage. By minimizing the distortion of the waveforms, the PFC power supply reduces the harmonics. Again, the power factor of each device installed within the data center can vary depending on its age and design.

More on Waveform Variations

Another type of power source deviation is waveform variations. The oscillation of voltage and current ideally follows a sinusoidal shape. Waveform variation occurs when the voltage or current waveform is altered from a sinusoidal shape. The distortion to the voltage and current waveform is often described as harmonics. Harmonics is a part of the waveform that oscillates more rapidly than the nominal frequency.

Harmonics have frequencies that are integer multipliers of the waveform's fundamental frequency (60 hertz fundamental; second harmonic = 120 hertz; third harmonic = 180 hertz; and fourth harmonic = 240 hertz). Total harmonic distortion is the summation of all the harmonic components of the voltage or current waveform compared to the fundamental part. Typically, odd-numbered harmonics give the most problems, like creating heat and other inefficiencies.

Linear loads, like household appliances (e.g., electric stoves and incandescent light bulbs), draw sinusoidal currents and do not distort the waveforms (no harmonics). Nonlinear loads such as switch-mode power supplies, variable speed drives, computers, and uninterruptible power supplies draw current in high-amplitude short pulses that significantly distort the electrical current and voltage wave shape (creating harmonics).

Harmonics or distortion in the waveform will travel back into the power source and affect other equipment connected to that source. Most power sources can accommodate a certain level of harmonic currents. However, as those harmonic currents become more significant, the following issues can occur:

- Overheating of electrical distribution equipment and cables.
- Equipment malfunctions.
- Higher voltages and circulating currents.
- Vibrations and buzzing.
- False tripping of protection devices.
- Generator failures.
- Increased energy losses and overheating cause component failure.

Let us go back and review the rack PDU power metering details outlined in Table 1 with added information on why these metrics supply value within a power infrastructure and help avoid some power quality issues before they arise. Table 2 below defines the power metrics and why determining and resolving power quality issues at the rack can facilitate trouble-free operation and the uptime of IT devices.

Table 2: Raritan and Server Technology Rack PDU Infeed & Outlet (Device) Power Quality Metrics Measurement's Values

Rack PDU Power Quality Metric	Measurement	Measurement's Value
Voltage, RMS	V_{RMS}	L-L and L-N at the Inlet / Infeed or Outlet.
Voltage, Neutral	V_N	High neutral voltage indicates the branch circuit wiring length is too long, a problem with the neutral wire or its connections (like a loose connection or improper installation), or excessive harmonic distortion. Neutral conductor monitoring is required by the EN 50600 standard for data centers.
Voltage, Harmonic Distortion	V_{THD}	Voltage harmonic distortion indicates a problem with the power source.
Voltage, Dip & Swell	V_{DIP} V_{SWL}	Dips and swells indicate high instantaneous current draws in the data center that is affecting the power source's ability to produce a stable voltage. Dips can also be an indication that there are problems in the branch circuit wiring.
Current, RMS	A_{RMS}	Current at the Inlet / Infeed or Outlet.
Current, Neutral	A_N	Indication of 3-phase load imbalance causing loss of efficiency (line losses) and heat.
Current, Inrush	A_{INRUSH}	Inrush current is a measure of how much current is drawn when power is first turned on and can cause circuit breaker trips if too high. Can be used to determine whether a switched PDU is required and if so, can be used to determine how to stagger the PDU's relay turn-on time of devices.
Current, Harmonic Distortion	A_{THD}	Current harmonic distortion can indicate a problem in the server power supply.
Crest Factor	CF	Is a measure of the peak to average current and an indicator of the presence of harmonic distortion if the value is above 1.41.
Watts	W	The power used to perform useful work.
Volt-Amps-Apparent Power	VA	Total power = active + reactive + harmonic.
Volt-Amps-Reactive Power	VAR	Power flowing in reactive components (capacitors/inductors). Does no useful work.
Power Factor, True	PF_{true}	Ratio of active power to apparent power. Example: 0.9 = 90% active power (doing actual work) + 10% reactive + harmonic powers.
Power Factor, Displacement	PF_{disp}	Ratio of active power to active + reactive powers. Example: 0.9 = 90% active (doing actual work) and 10% reactive powers.
Power Factor, Distortion	PF_{dist}	Is a direct measurement of the inefficiency due to harmonic distortion. A Distortion Power Factor of 0.95 indicates 95% of the power is being put to useful work and the remainder is wasted on producing harmonic distortion.
Energy	kWh, kVA	Accumulated active power: 1 = 1000 W accumulated over 1 hour. Accumulated apparent power: 1 = 1000 VA accumulated over 1 hour.

UNIQUE FEATURES OF ADVANCED PDU TECHNOLOGY PLATFORMS

Circuit Breaker Trip Forensics

On any PDU rated over 16A, UL requires overcurrent protection on a rack PDU with devices like circuit breakers or fuses. To ensure efficient power delivery, the number of branch circuits needed in a PDU is proportional to the input power. For example, a 3-Phase Wye 32A 400V PDU requires six branch circuits rated 16A each to distribute all available current. It's important to keep in mind that if there is an overcurrent event on a branch circuit of a PDU, the device will trip and shut off all outlets on that specific circuit. This can lead to potential issues, especially if redundant A and B PDUs are not loaded properly or if the OCPDs are not coordinated between the PDU's breaker and the breaker in the RPP. In some worst-case scenarios, this may result in the PDU losing power and shutting down the whole cabinet. It is suggested that a coordination study is done between the PDU's breakers and the panel's breakers and that redundancy checks are performed to ensure if power is lost on one of the PDUs that the other one can carry the whole load.

If a PDU's OCPD does trip, the usual procedure for recovery is,

- Locate the breaker that tripped on the PDU,
- Locate its related outlets/branch circuit,
- Unplug all the devices on that PDU's branch circuit,
- Reset the breaker, and then,
- Start plugging the devices back in until the breaker trips again.

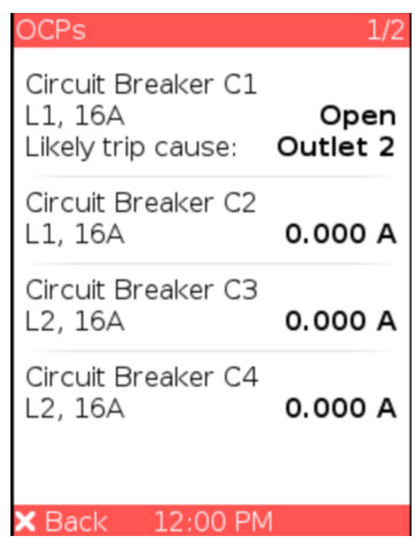


Figure 7: PDU's LCD Screen Showing a Circuit Breaker Trip Event

Finding an outlet/device that tripped the breaker is the first step; a slow and time-consuming recovery process remains. PDUs equipped with enhanced circuit breaker trip forensics identify the specific outlet and, therefore, the device that caused the trip, saving time when investigating and resolving issues. Once a PDU's OCPD has tripped, information is provided both in the PDU's web GUI and on the PDU's controller LCD identifying where the problem is.

There are two waveform capture types when power events have occurred: 1) on-demand and 2) capture triggered by an event like an OCPD tripping. On-demand is triggered manually by the user, and automated events are triggered once per OCPD based on the suspected outlet. The waveform is captured at the moment of invocation and is only valid for that event. Subsequent events will trigger a new capture. Waveform captures can be automated based on specific events or started on-demand through the PDU's web GUI or APIs.

Typical events that automatically trigger a waveform capture are when,

- PDU's outlet is switched on to look at the inrush waveform per outlet,
- There is an OCPD trip event, as previously mentioned,
- There are voltage dip and swell events, or
- There is an on-demand waveform capture for a PDU's outlet or inlet.

In data centers, waveform capture can help identify power quality problems. For example, when a power supply fails or blows up, the PDU can capture the current and voltage values at the rack via a waveform capture in a brief period to gather the cause of the issue, which is most often its current surge.

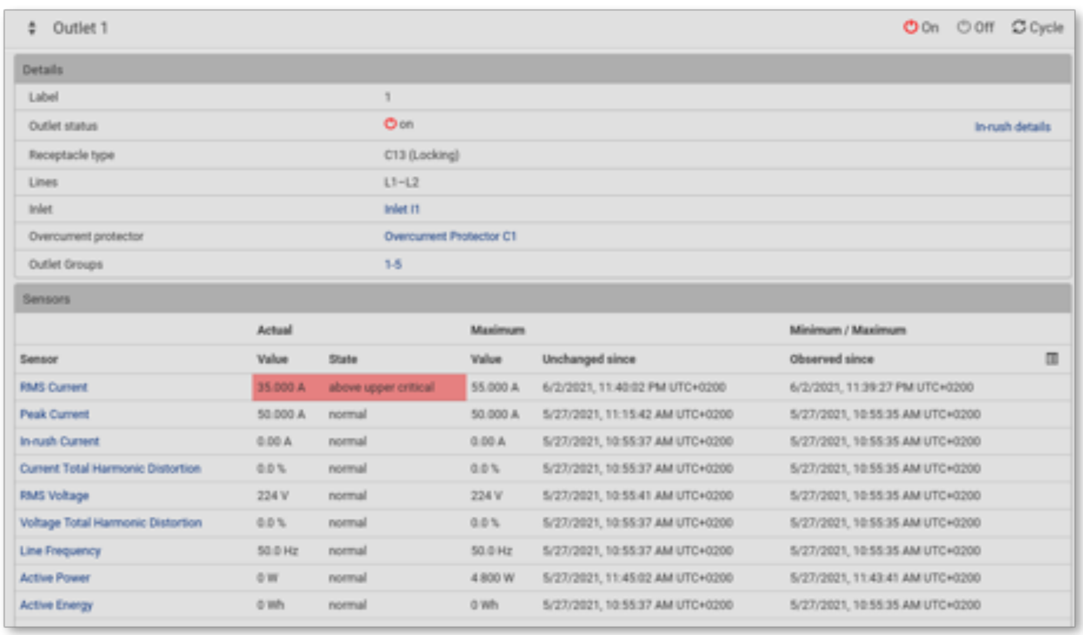


Figure 8: Raritan and Server Technology's PDU Web GUI Capturing Power Quality Events

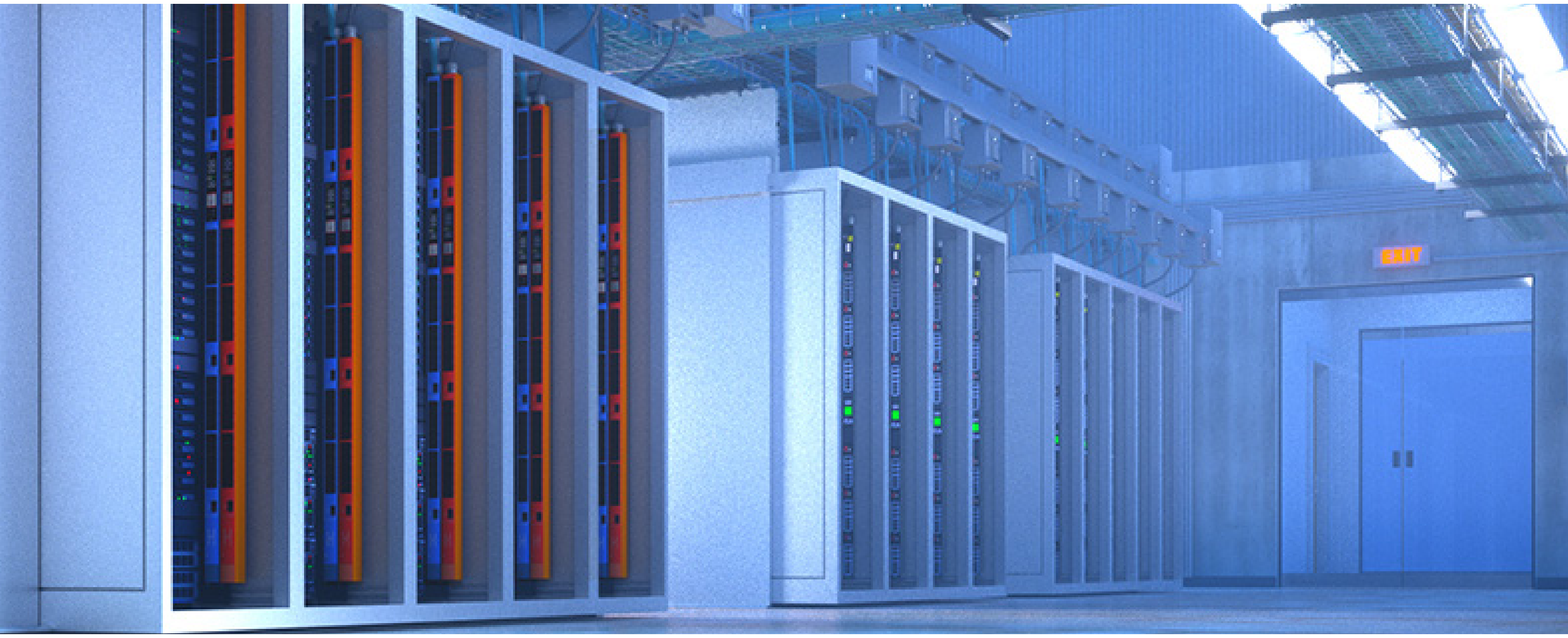
POWER QUALITY AND CONSUMPTION

Min and Max Values Provide a World of Information

Though power quality and usage information are interesting at a particular point in time, overall, these meters have the most value when looked at over a longer period. Only then can a data center get an actual perspective on what is going on within its environment.

For example, if installing a new server into a rack and going into the power information of the PDU/cabinet, the total load of the cabinet at that point in time will be known. But the user wants to know the worst case so that if the power demand is greatest on Cyber Monday, they would already know if they had the resources (whether it is power or cooling) to install that server into a particular rack under those worst-case conditions. The same is true when looking at power quality metrics and deciding how bad of a harmonic distortion problem exists. Again, identifying the worst case is what is needed and not what is going on at that specific point in time.

This PDU feature—the ability to measure rack level peak and minimum/maximum power quality measurements allows the user to look at power information like a minimum-maximum "thermometer" that keeps track of the readings. Where the PDU stores this information, the user can reset the values at any time to better understand their power quality problems and how the steps taken to resolve them are working. It is like a "DCIM type" tool, but it is already built into the PDU, allowing the user to make informed decisions without consulting other systems or tools. These rack-level power quality measurements are found at the PDU's infeed and outlets and at any location along the PDU where power monitoring and power quality metrics are available.



IN CONCLUSION

Data centers need an extremely high degree of electrical reliability and safety. An awareness of power quality issues and how to address them, down to the rack level, is necessary for those who want to protect their bottom lines from the prohibitive downtime costs. In general, power quality issues can make power infrastructure unstable, causing unforeseeable rebooting of IT equipment or leading to more critical scenarios such as equipment overheating, a circuit breaker or fuse malfunction, or IT hardware damage. As power quality patterns become recognizable over time, a long-term monitoring strategy can help identify what processes are leading to a critical situation to prevent similar cases from occurring again. It also helps to adhere to availability levels and potentially avoid penalties in case of service level agreement infringements. Service interruptions may have a lasting impact on a data center's operations and the business, both in terms of missed revenue and loss of consumer confidence in the services provided.

Once one or more power quality problems are identified, a proper plan can be derived to mitigate these issues. Using Legrand's next-generation Raritan PX4 or Server Technology PRO4X branded intelligent rack PDUs that include built-in advanced power quality metrics and diagnostic tools, both at the PDU inlet or what is often called the PDU infeed, and at the PDU's outlets is a start! Without an intelligent PDU with the proper built-in power quality meters, one would have to install external meters throughout the power chain to provide continuous power quality monitoring to detect power quality problems. These power quality meters should include capturing and viewing waveforms, detecting disturbances like voltage sags and voltage swells, measuring harmonic power flow, and providing alarms when measurements are outside a set tolerance range. They will also need connectivity back to management systems to track and monitor events. If a data center chooses to install an intelligent PDU that already has embedded power quality measurement capabilities, audit tracking, and performance analytics will already be well on their way to being optimized.

Learn more about Raritan and Server Technology Rack PDUs.

References

1 Data Centre Demand Response: Geographical Load Balancing for Distributed Generation Integration in Low Voltage Networks

2 How Much Energy Do Data Centers Really Use?

3 Uptime Institute Tier Standard: Topology

4 Power Quality Monitoring & Its Impact on Today's Data Centers

5 Understanding Importance of Power Quality in the Data Center—Finding the Ghost in the Machine

6 2023 Uptime Institute Annual Outages Analysis

7 IEC 61000-3-2:2018