

Power Efficiency Gains by Deploying 415 VAC Power Distribution in Data Centers

EXECUTIVE SUMMARY

High physical density and high power density go “hand in hand” in the data center. To maximize both without paying for specialty infrastructure, many data centers have found it attractive to deploy 415V 3-phase AC power to the rack. This paper gives the reasons why this is a cost-effective alternative for many applications.

OVERVIEW

Within enterprise data centers, power is used for operating the facility, lighting, running IT loads, and cooling. It is the largest component of the facility’s operational expense (OPEX). The Green Grid has published numerous papers and articles, including The Uptime Institute, PG&E, Lawrence Berkeley National Laboratories (LBNL), and others discussing measuring, monitoring, and increasing efficiencies. This paper discusses various approaches to reduce power consumption and increase end-to-end efficiency in the data center by bringing 415 VAC power to the IT cabinet/rack level. With power densities continuing to rise, more efficient solutions continue to be explored, especially as power costs increase and power availability decreases. The power path from the building entrance to the IT loads contains several power converters and transformers to perform each conversion, and during the stepdown process, there is a loss of power. Reducing the number of transformers and operating at a higher voltage improves efficiency and reduces electrical costs. We’ll explore an alternative approach to power distribution presently being implemented in North American data centers that increases efficiency and savings by reducing upfront capital costs, power consumption, and floor space.

BASELINE: CURRENT NORTH AMERICAN 208 VAC 3-PHASE POWER DISTRIBUTION

In North America, 277/480 VAC, 3-phase power is delivered to most large commercial buildings and IT facilities. The voltages are measured from line-to-neutral (277 VAC) and line-to-line (480 VAC), as shown below in Figure 1. Automatic switching power supplies inside IT equipment typically operate from 100 VAC to 240 VAC single-phase, so the utility power delivered to the facility must be stepped down from 277 VAC through isolation transformers before it may be used as depicted in Figure 3. This is achieved by routing the facility power through an end-of-row Power Distribution Unit (PDU) transformer, which is stepped down from 480 VAC 3-phase to 208 VAC 3-phase.

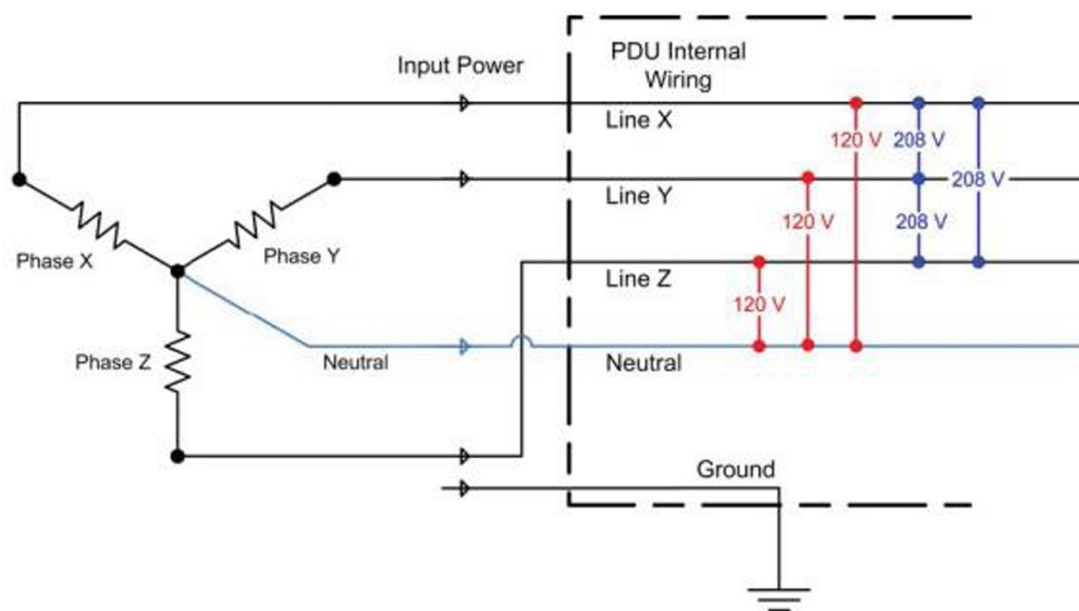


FIGURE 1: 208 VAC 3-phase after the PDU transformer

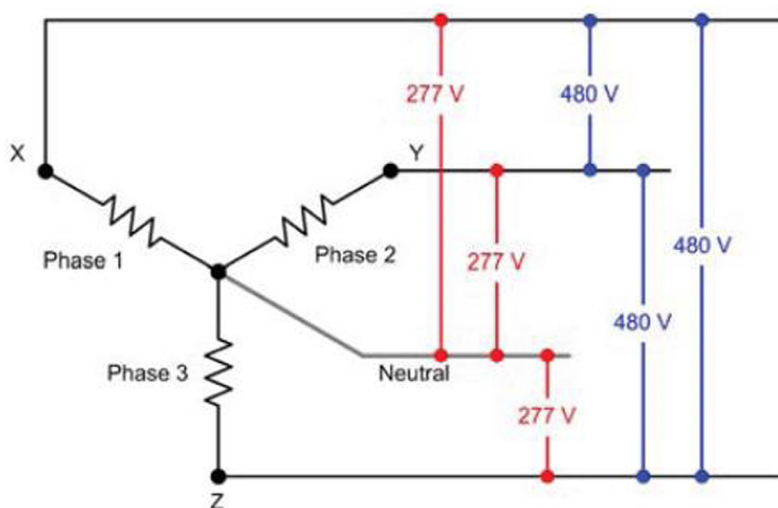


FIGURE 2: 480 VAC 3-phase power at the building entrance 120 VAC line-to-neutral

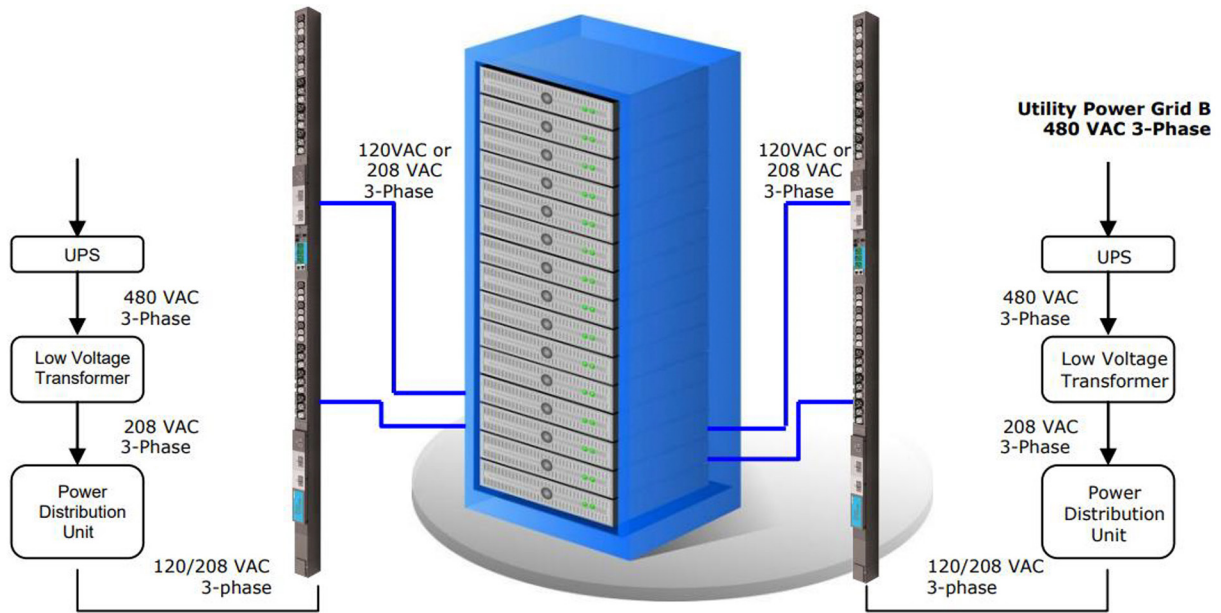


FIGURE 3: 480 VAC 3-phase to 208 VAC power path

From the end-of-row PDU, power is typically distributed in one of three formats by remote power panels (RPP) or rack-level power distribution units (PDUs):

1. 120 VAC single-phase (measured line-to-neutral)
2. 208 VAC single-phase (measured line-to-line)
3. 208 VAC 3-phase (in a Delta or Wye configuration)

Most IT devices have automatic switching power supplies that accept low-line voltages of 100-120 VAC and high-line voltages of 200-240 VAC. Running devices at the higher voltage increases efficiencies in the range of 2 to 2.5 percent, so the first step towards optimizing efficiency is for data center managers to ensure that all devices capable of operating at 208 VAC are doing so.

In 208 VAC distribution systems, 208 VAC is implemented with a line-to-line configuration (taking 2 of 3 lines of 3-phase power) to the rack PDU versus a line-to-neutral configuration for 120 VAC in Figure 2. The advantage of this 208V system is the capability of delivering 120 VAC for legacy devices; however, as mentioned before, most devices have universal power supplies capable of operating at higher voltages.

Keep in mind that within the IT device's internal power supply, power goes through one more transformation and conversion in which 120 VAC or 208 VAC is stepped down and then rectified to 12 VDC and other working voltages using DC-DC conversion circuitry. See Figure 4.

New demands for supporting big data, artificial intelligence, and other intense compute loads combined with the quest for efficiency improvements are causing higher power densities at the cabinet level, leading to new data center designs with 208 VAC 3-phase distribution are being replaced with 415 VAC 3-phase systems.

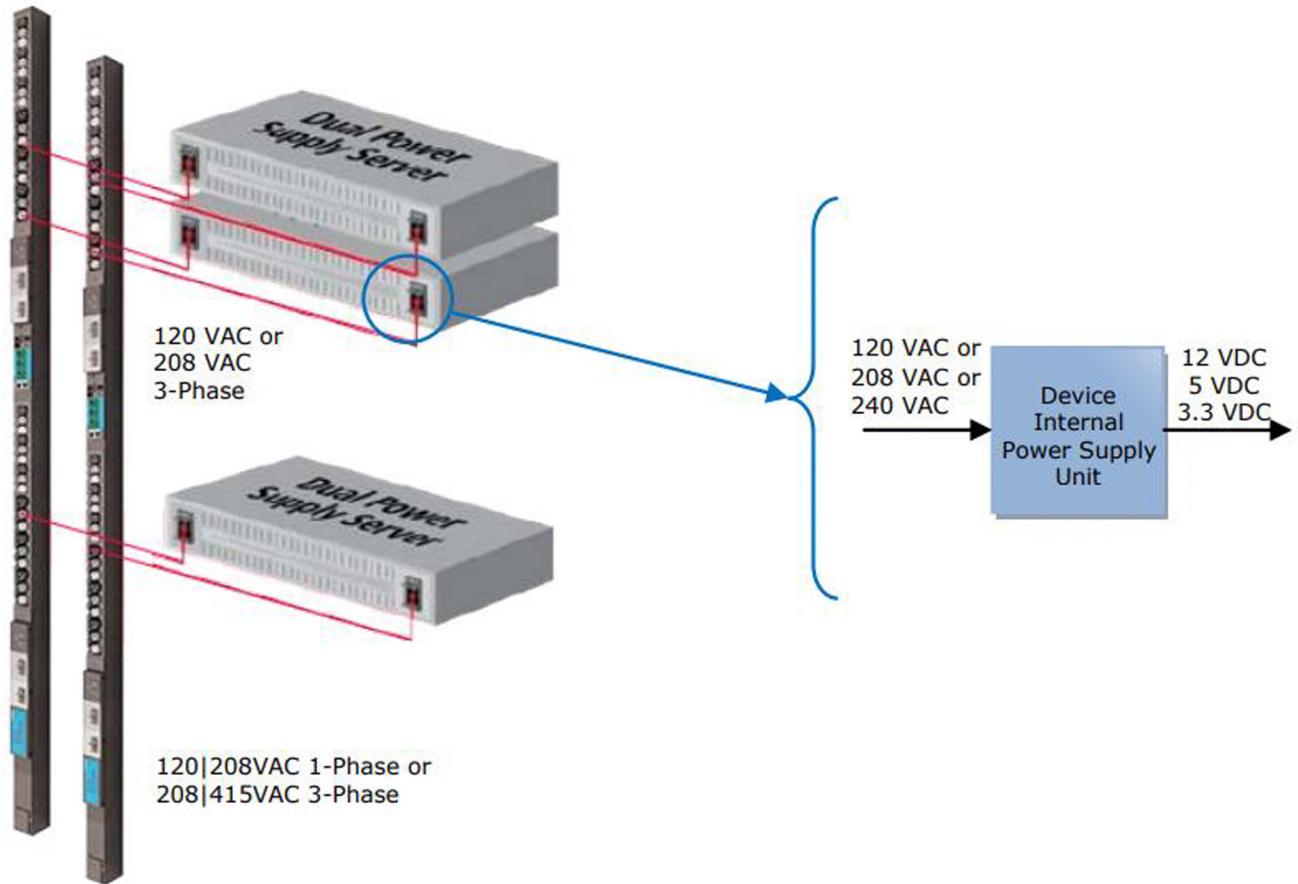


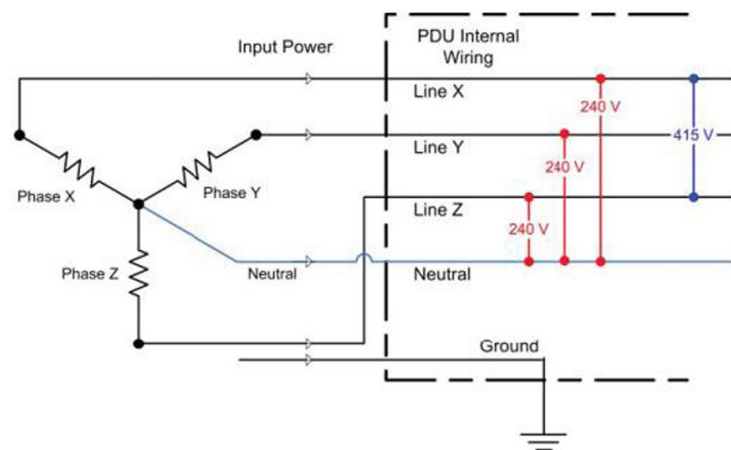
FIGURE 4: Power distribution within the rack

415 VAC 3-PHASE POWER DISTRIBUTION

Power and cost savings in the data center can be achieved by reducing the number of power transformations and by operating at higher voltages. This can be done by converting the UPS output from 277/480 VAC to 240/415 VAC through an autotransformer and eliminating the PDU transformer. Alternatively, the PDU transformer may be replaced with a PDU autotransformer. In a 415 VAC distribution system, the line-to-neutral voltage is 240 VAC. It is important to note that this is a significant difference from the typical U.S. Baseline System, where the line-to-neutral voltage is 120 VAC after the PDU transformer. This approach doubles the voltage delivered to the devices while increasing efficiencies and reducing installation costs by eliminating components and using smaller diameter cables for distribution.

The 415 VAC power distribution system that is used in much of the world outside of North America is now beginning to gain a foothold within the U.S. and Canada. According to various UPS manufacturers, eliminating the PDU transformer will result in a 2 percent efficiency gain.

415 VAC 3-PHASE



208 VAC 3-PHASE

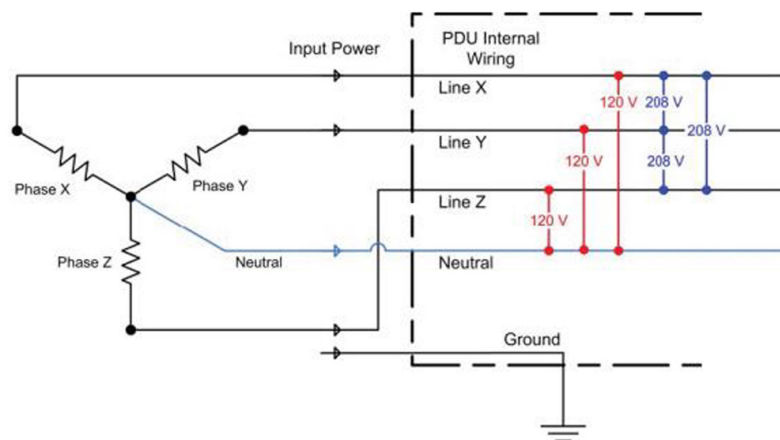


FIGURE 5: Difference between 415 VAC and 208 VAC power distribution systems

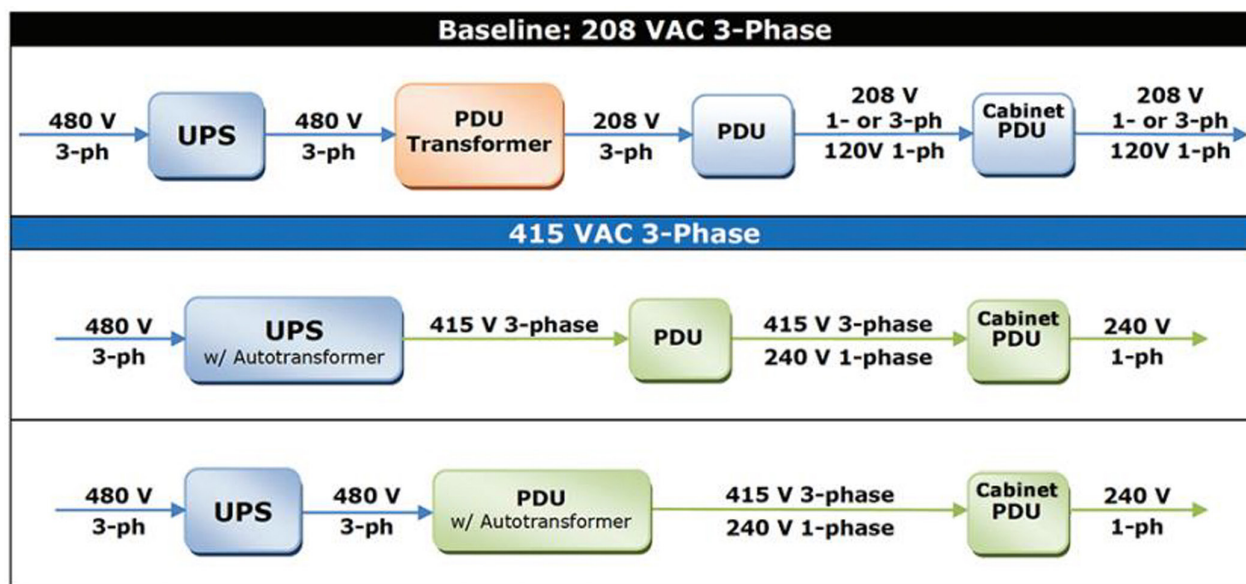


FIGURE 6: Comparison between the baseline power path and the 415 VAC power path with the elimination of the PDU transformer

Additionally, operating rack-level equipment at 240 VAC versus 208 VAC will provide an added 0.2 percent to 0.3 percent efficiency gains as shown in Table 1 for the HP ProLiant DL385.

Input Voltage Range (V rms)	100-240					
Frequency Range (Nominal) (Hz)	50-60					
Nominal Input Voltage (V rms)	100	120	200	208	230	240
Maximum Output Wattage Rating (Watts)	500	500	500	500	500	500
Nominal Input Current (A rms)	5.6	4.6	2.7	2.6	2.4	2.3
Maximum Input Wattage Rating (Watts)	557	550	539	539	537	537
Maximum Rated VA (Volt-Amp)	563	556	545	544	543	542
Efficiency (%)	89.7	90.8	92.7	92.8	93.1	93.1
Power Factor	0.99	0.99	0.99	0.99	0.99	0.99

TABLE 1: HP ProLiant DL385 Gen10 Flex Slot Power Supply

To better understand the benefits of a 415 VAC system, consider what is necessary to deliver redundant power to a rack of high density blade servers. Using the power configuration calculator from a major blade system manufacturer, the power requirement for four fully populated blade systems is 15.1 kW. Table 2 below shows four different approaches to delivering this amount of power to the rack along with the number of power drops needed to provide redundancy.

Voltage	Phase	Current	kW	kW Continuous Rating	Power Drops Required	Total Drops for Redundancy
415	3	30	21.6	17.3	1	2
208	1	30	6.2	5.0	4	8
208	3	30	10.8	10.8	2	4
208	3	60	17.3	17.3	1	2

TABLE 2: Power Capacity Comparison Voltage

<p>415 VAC SYSTEM $30\text{ A} \times 3 \times 240\text{ V} \times 0.80\text{ de-rating} = 17.3\text{ kW}$</p>	<p>208 VAC 1-PHASE, 30 A SYSTEM $30\text{ A} \times 208\text{ V} \times 0.80\text{ de-rating} = 5.0\text{ kW}$</p>
<p>208 VAC 3-PHASE, 30 A SYSTEM $30\text{ A} \times 1.732 \times 208\text{ V} \times 0.80\text{ de-rating} = 8.6\text{ kW}$</p>	<p>208 VAC 3-PHASE, 60 A SYSTEM $60\text{ A} \times 1.732 \times 208\text{ V} \times 0.80\text{ de-rating} = 17.3\text{ kW}$</p>

Efficiency gains by implementing a 415 VAC design are typically 4 to 5 percent, see Figure 7. Upfront cost savings are also realized by eliminating the PDU transformer, using smaller gauge power cords and less expensive plugs, taking up fewer poles at the breaker panel, and requiring fewer power drops to the cabinets. Added savings come from reductions in cooling costs with the elimination of the PDU transformers and at the cabinet level by having fewer PDUs and cable drops which can impede airflow. Additionally, though a 208 V, 60 A system provides the same power as a 415 V, 30 A system, lower current flow allows smaller conductors, thus lowering the initial costs and reducing line losses due to cable resistance.

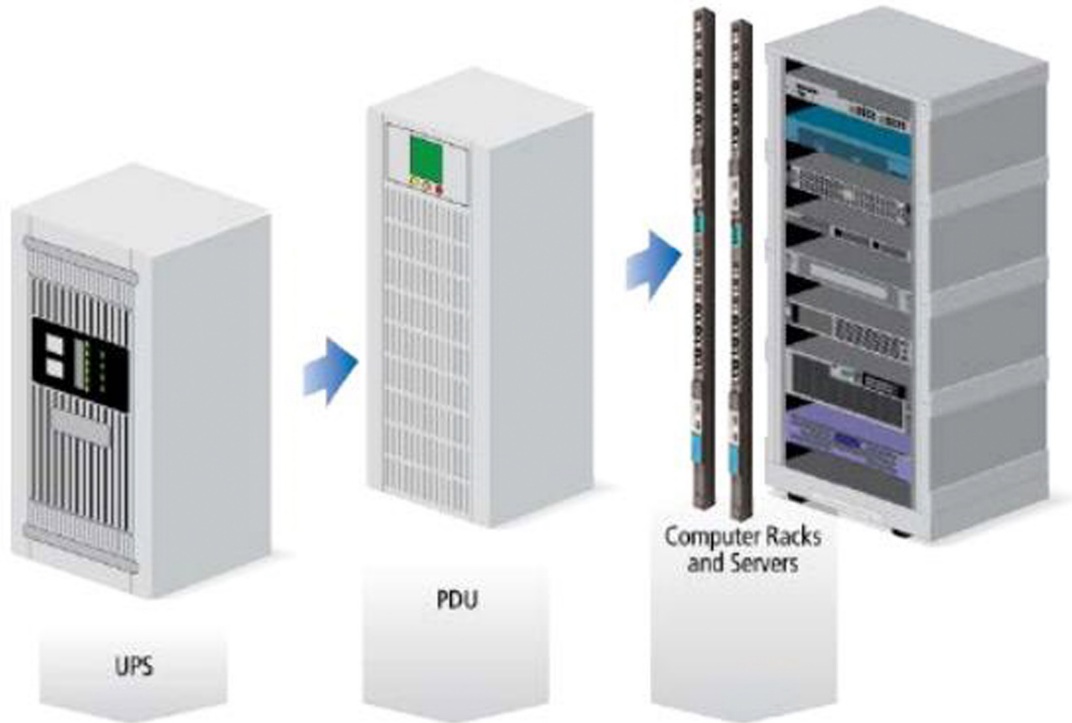


FIGURE 7: Efficiency gains by eliminating the transformer and running equipment at 240 V rather than 120 V

IT Load (kW)	1%	1%	3%	4%	5%
250	\$2,190	\$4,380	\$6,570	\$8,760	\$10,950
500	\$4,380	\$8,760	\$13,140	\$17,520	\$21,900
750	\$6,570	\$13,140	\$19,710	\$26,280	\$32,850
1,000	\$8,760	\$17,520	\$26,280	\$35,040	\$43,800
1,500	\$13,140	\$26,280	\$39,420	\$52,560	\$65,700
2,000	\$17,520	\$35,040	\$52,560	\$70,080	\$87,600

TABLE 3: Annual energy savings from efficiency gains

DISTRIBUTING 415 VAC AT THE CABINET LEVEL

Power to the IT loads is distributed through a cabinet PDU at the cabinet level. A PDU designed for 208 VAC 3-phase systems is incompatible with 415 VAC systems because it is wired line-to-line. To deliver 240 VAC single-phase, the outlets must be wired line-to-neutral. Server Technology offers rack PDU designs that meet these requirements. The HDOT PRO2 Switched PDU with Server Technology's Alternating Phase outlets below that offer a combination of IEC 60320 C13 and C19 outlets. See Figure 8.

The picture shows an example of a cabinet PDU configured for 415 VAC service. This particular PDU has two outlet sections, each with three phases and two circuit breakers per phase, allowing it to deliver 17.2 kW, which is the full capacity of the circuit. With this design, if the current in Branch 1 exceeds 20 A, it will trip the breaker and remove power to the branch leaving the rest of the PDU running normally.

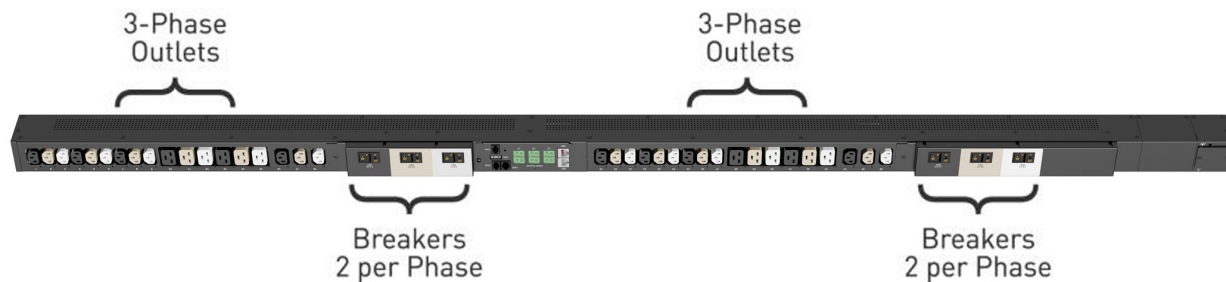


FIGURE 8: Server Technology Cabinet Power Distribution Unit

POWER MONITORING USING SERVER TECHNOLOGY POPS™ (PER OUTLET POWER SENSING)

To best manage power utilization, the capability to measure and monitor it must be present. The cabinet PDU is the most intelligent device closest to the IT load. It is an ideal point to monitor power consumption. Intelligent PDUs (such as Smart or Switched PDUs) are equipped with local displays that provide helpful information at the cabinet when powering up and load testing; however, they offer little accessible information over a day, week, or month when placed inside a cabinet that remains closed and is infrequently visited by personnel. Since power draw varies over time, PDUs are designed to be networked and allow power information to be queried, polled, and trended at both a circuit and outlet level, provide data center and facilities managers a better understanding of actual equipment power usage and identify underutilized equipment or stranded power capacity.

Information can also be rolled up so power usage can be viewed by device, at an application level, or a cabinet, row, or floor level. Additionally, the accumulated data may be used to calculate the PUE (Power Usage Effectiveness) and other metrics established by The Green Grid and other organizations to gauge and analyze power consumption and efficiency.

ENVIRONMENTAL MONITORING

Maintaining the proper temperature and humidity range within the cabinet has become critical due to increased densities and server utilization due to virtualization and containerization. Server Technology cabinet PDUs support plug-and-play sensors that monitor and report on environmental conditions before they affect or jeopardize the performance and lifespan of IT assets. When used with a DCIM tool, temperature, humidity, and power trends may be logged and analyzed.

120 V IT DEVICES

Some IT equipment may be supplied with a 120 VAC NEMA power cord that will not be compatible with the cabinet PDU in a 415/240 VAC distribution system. Fortunately, most IT equipment manufacturers use power supplies that accept 100 V to 240 V and have standardized IEC connectors for their products, such as Legrand's Raritan Dominion KX III KVM-over-IP switch, which is designed with an IEC 60320 C14 inlet. This allows the power cord to be changed to an IEC type cord. For those devices that do not have universal power supplies that will accept 240 VAC, rack-mounted transformers are available from several vendors.



FIGURE 9: Legrand's Raritan Dominion KX III KVM-over-IP Switch with IEC C14 inlet



FIGURE 10: IEC 60320 outlets and plugs to connect IT equipment to the PDU

SUMMARY

With small data centers operating in tens of kW and large data centers running in tens of MW, incremental efficiency increases can translate into significant savings. Several other proposed power distribution architectures are being discussed in the IT industry, such as rack-level and facilities-level DC power distribution and 277 VAC distribution, which have not yet been widely adopted.

For the time being, most data centers find that distributing 415/240 VAC power to the IT rack is the most cost-effective and efficient solution available. Server Technology supports a broad range of cabinet PDUs that support 415/240 VAC 3-phase power for the most demanding data center requirements.

ABOUT SERVER TECHNOLOGY®

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