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Battle of the Power Distribution Strategies

by Dennis Julian, PE, ATD, DCEP

120 volt (V) alternating current (ac) is the most inefficient of all the available power options because it requires the highest current to provide the same power. As designers, we are obligated to explore new and other readily available options. The contenders are 480/277 V ac, 400/230 V ac and 550 V direct current (dc). Each has its advantages.

For the past several years, the focus of data center designers has been on energy efficiency. Driven by high energy costs and looming government regulation, engineers have utilized a metric developed by The Green Grid called power utilization effectiveness (PUE) to benchmark and evaluate various new design strategies. PUE simply compares the total energy utilized with the energy used by the IT equipment. The greater the percentage of total power used by IT equipment, the lower the PUE is for the data center. Based on that paradigm, designers initially looked to the mechanical systems to identify and eliminate wasted energy. The result of this effort has been tremendous. Today's data centers that adopt the many creative cooling design strategies currently offered often use 50 to 80 percent less energy than legacy facilities.

The focus on the electrical side has been on the efficiency of the equipment. Manufacturers have done a great job of making their new equipment much more efficient than past generations. The simplest and most cost effective example of these gains is providing a much more efficient power supply with each server. Old power supplies had efficiencies approaching 70 percent; however, currently, a 90 percent or more efficiency is common. Gains in other equipment such as the uninterrupted power supply (UPS) have been similar, albeit less dramatic.

As designers continue to squeeze energy efficiency out of obvious power hogs in the data center, they have started to focus on less obvious targets. One current focus has been on the power losses in distributing power inside the data center. This has resulted in a debate as to which power distribution alternative is best for data centers. Today's U.S. standard is 120/208 volt (V) alternating current (ac). This traditional design delivers usable power to the rack that can support servers running on ac power, which ranges from 120 V to 250 V. Most currently made servers are delivered with power supplies that can be plugged into any voltage from 100 V to 250 V by using different standard cord and plug sets. Large-scale users often employ the more efficient 208 V servers. This simplicity in power alternatives has served computer manufacturers well, as it has simplified manufacturing and distribution logistics.

Power is calculated by multiplying voltage by current ($P = VI$). Power loss is calculated by multiplying the square of the current by the resistance of the system ($P_L = I^2R$). To reduce losses, the current should be reduced, which is accomplished by rais-

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ing the supply voltage. 120 V ac is the most inefficient of all the available power options because it requires the highest current to provide the same power. As designers, we are obligated to explore new and other readily available options. The contenders are 480/277 V ac, 400/230 V ac and 550 V direct current (dc). Each has its advantages.

480/277 Volt

Power coming to the building from the utility is most commonly 480/277 V ac. Since distribution of power is more efficient at a high voltage, designers are considering IT equipment based on 480/277 ac. This system will reduce power losses in the data center electrical distribution system and reduce the amount of copper needed to build the facility, as the wire sizes are significantly smaller at a high voltage. Additionally, using the power at 277 V eliminates a transformer to get to 120/208 V and its inherent power losses and capital costs. The problem with this alternative is that 277 V ac is above the Underwriters Laboratories Inc.® (UL®) and National Electrical Manufacturers Association® (NEMA®) standards range of 250 V ac for plugs and receptacles. Being outside industry known and accepted standards makes owners and equipment manufacturers uncomfortable. Unless user and manufacturer demand drives an effort to change these standards, it will remain a relatively small niche market. The cost and effort to develop and approve a new standard and then to test and approve all of the equipment will take significant time and money. Who will want to take on that challenge in a market that changes so rapidly?

Mark Monroe, chief technology advisor of Integrated Design Group and executive director of The Green Grid, is skeptical of the chances for 480/277 V. He states, "It is complicated to qualify new power architectures for the system, storage and networking vendors. Supporting multiple architectures is expensive from a certification and support standpoint. It's hard for a manufacturer to make a change without a significant commitment from purchasers to move to the new standard, either through industry action or regulation. Also, the advantage we are talking about is three to eight percent, so a careful design using high efficiency products for UPS, PDU and computer configura-

tion could eclipse the savings from power system design alone."

400/230 Volt

Jack McCarthy, principal at Integrated Design Group in Dallas, is a believer in higher voltage ac power distribution in data centers. Based on his design work in Saudi Arabia and other Middle East countries, Jack has embraced the 400/230 V standard that is used there and in many parts of the world. Jack is promoting its use in the U.S. whenever possible because of its reduced energy usage and lower construction costs. He states, "This is a proven technology with thousands of installations worldwide. The only thing holding back using the 400/230 V standard here in the U.S. is getting the equipment manufacturers for both the power distribution and the IT equipment to make the gear that they have already designed, tested and distributed in Europe and the Middle East available here in the U.S. It should be a no-brainer."

This solution has many of the same benefits as the 480/277 V solution without the changing standards obstacle. So what is the problem? 400/230 V distribution is very unusual in the U.S., and equipment manufacturers are hesitant to take on the cost of adding an entire product line running at a different voltage level without some guarantee that there will be a significant return. Manufacturers have been trying to lower distribution costs by streamlining product offerings for years. Adding a new standard is not a simple task in a down economy; therefore, end users who want to use this design are required to order custom equipment, often at a cost premium. Many data center owners are shying away for this reason. End user groups will need to begin to demand that manufacturers start to make this equipment more readily available. If the manufacturers see a market, they will support it. In today's global economy, it does not seem reasonable to not make readily available in the U.S. equipment, which is in use globally.

380 to 550 Volt dc

48 V dc has been the power of choice for telecommunications companies for years. The low density equipment was ideal for the highly reliable dc systems that were implemented. However, the power losses distributing 48 V in higher density applications are staggering. Additionally, when these organizations implemented larger build-outs in the dot-com era, they discovered that the sheer volume of copper required to distribute power at low-voltage created structural issues, which is to say nothing of the high cost of copper. For those reasons, dc power has not been utilized for general IT equipment loads in large-scale data center applications.

Livermore Berkley National Laboratory (LBNL) investigated higher voltage dc distribution in the data center for general IT equipment. The report, *DC Power for Improved Data Center Efficiency*, indicates that the high voltage dc (380 V in the study) system can improve the efficiency of the data center more than 28 percent compared to a typical data center and more than seven percent compared to a best in class high-efficiency data center.

In an effort to reduce energy usage, Rudy Krause at Validus systems (now a division of ABB) developed a proprietary system that distributes power at 550 V dc (to minimize the current required for the same power) and steps the power down to 48 V dc at the cabinet. Our team at Integrated Design Group reviewed the system several years back. Tests show that the system delivers on the energy savings promised and the installation and operation of the equipment was straightforward and surprisingly simple.

Promoting this system, Krause has been the number one advocate for dc power over the past five years. The benefits of dc power include the following:

- The transformer and the UPS can be eliminated as there is no need to clean the power before it gets to the server.
- 48 V dc is what the IT professional is comfortable with and has been using at the rack for years.
- Since the servers run on dc power, eliminating the power supply has a significant effect even with the newer high efficiency power supplies.

Additionally, in the world of alternative energy, using dc power simplifies incorporating alternative energy sources such as photovoltaic, wind or fuel cells, as these technologies produce dc power and can simply be incorporated into the dc distribution system.

The downside to dc power distribution is two-fold. First and foremost is the comfort level of personnel working with high-voltage dc power. Many are simply not trained in or comfortable with it. Second, like the other technologies, the equipment is not readily available. Again, this can be overcome by manufacturers making a commitment to the technology, but they seem hesitant. Manufacturers are heavily entrenched in the ac world, and they will only move from that if the end users push them in that direction. Likewise, clients need to request that the manufacturers move in this direction. Generally, clients show an interest; however, the marginal gains that dc power has over the high-voltage, efficient ac system just does not seem great enough to gain their interest as they see more effective ways to spend their R&D dollars.

Conclusion

I believe that the 480/277 V system will emerge as the new standard for U.S. data centers. All of the alternative distribution systems discussed will require manufacturers to invest in agency standards and approvals. However, the 480/277 V system will focus those changes at the IT equipment level, simplifying the process. It only requires a power supply and outlet change—not an overall recertification of distribution equipment. ■