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AC vs DC Power in the Data Center

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Most data center installations today use AC power distribution to the IT equipment. However, from time to time, beginning in the early 1990s, various manufacturers and engineers have suggested that a change to DC distribution was advantageous and predicted a widespread adoption of a DC standard for data center power. In fact, the opposite has occurred, and the usage of DC relative to AC has declined. Recently, new proposals have been made based on high voltage DC distribution. These methods overcome some of the earlier problems with DC power. In this article, we will explain the characteristics, features and limitations of AC and DC distribution.

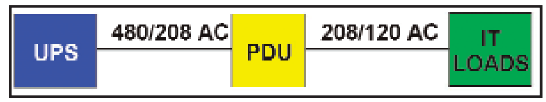

Figure 1a - Common AC Distribution in North America

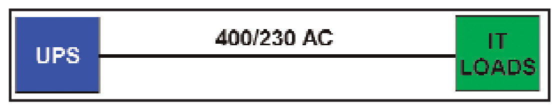

Figure 1b - Common AC Distribution Outside North America

AC and DC Distribution Possibilities

It is often assumed that when we talk about AC vs. DC distribution that we are comparing two alternative approaches. There are actually at least five power distribution designs that are commonly discussed during these comparisons, each with different efficiencies, costs and limitations. These five basic power distribution approaches are shown in the figures below. For each of the five basic types in the figures, the utility AC power enters from the left and the end point on the right represents the internal distribution voltage within the IT device.

Figure 1a represents the common AC distribution system in North America. The power goes through a UPS and a transformer-based power distribution unit (PDU) before entering the IT device power supply. There are five principal losses generated in this system: the UPS losses, the primary distribution wiring, the PDU losses, the branch circuit distribution wiring and the IT power supply.

Figure 1b represents the common AC distribution system used outside of North America. Note in this case the PDU transformer and the associated losses are eliminated because there is no need to step down the UPS voltage.

Figure 1c represents a typical Telecom DC power plant. A DC UPS provides 48 VDC for distribution to the DC powered IT loads.

Figure 1d represents a hypothetical approach distributing high voltage DC. IT devices designed to accept high voltage DC inputs would need to exist to allow this to work.

Figure 1e represents a hypothetical hybrid DC system. This system works with IT devices designed to accept 48 VDC but uses a high voltage DC UPS. It combines some of the attributes of Figure 1c and Figure 1d. Let's compare how these five systems perform against efficiency, cost, compatibility and reliability.

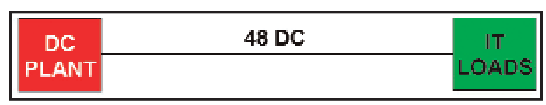

Figure 1c - Typical Telcom DC Power Plant

Figure 1d - Hypothetical Approach for Distributing High Voltage DC

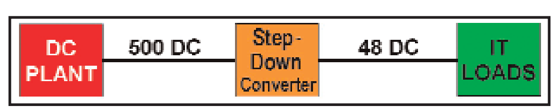

Figure 1e - Hypothetical Hybrid DC System

Efficiency

A principal argument put forth for the use of DC power in data centers is that it improves electrical efficiency far above AC power. This is based on the logic that some steps of power conversion are eliminated, resulting in reduced losses. The losses in a power system can be considered to occur in the following places: generation of uninterruptible power, distribution of power and in the utilization of power by IT equipment.

APC has developed a data center efficiency model that accurately describes the efficiency of a data center at varying loads (from 0 percent to 100 percent). Based on this model, we analyzed the five power distribution approaches described earlier and came to significantly different conclusions than the various publications out there asserting that AC power is significantly lower in efficiency than the DC approach.

It was found, in general, that other published work in this area used assumptions that gave rise to these differing conclusions. Two primary reasons are:

1. Other similar studies comparing DC and AC distribution do not model the variation of device efficiency with load. This causes substantial errors in the results.

2. Other studies assume values for AC device efficiency that are based on historic products and not representative of what is currently available, yet these are compared with hypothetical best-case DC products. For example, a recent article assumes an AC UPS efficiency value of 74 to 96 percent against a single hypothetical DC UPS efficiency value of 97 percent. In contrast, the off-the-shelf APC Symmetra MW UPS has an independently certified efficiency of 97 percent sustained over a range of 56 to 100 percent load. This is a massive error that completely accounts for the discrepancy between the results obtained in the analysis.

So in the end, the analysis begs the question: Are these small improvements in electrical efficiency for high voltage DC power distribution substantial enough in dollars to warrant a complete change in distribution architecture? Let's look further into the costs.

Cost

The cost of a DC power rectifier/battery plant is typically lower than an AC UPS system by 10 percent to 30 percent. However, the additional engineering and wiring distribution costs associated with DC offset this savings. The DC advantage is greatest in small low-density installations with minimal distribution costs, such as cell tower base stations. In data centers, the need to power some AC-only equipment increases cost of a DC system. The cost premium for DC powered equipment such as servers or storage is also a disadvantage in a DC system. However, the biggest cost problem for a low voltage DC plant is the distribution wiring to the IT equipment. It requires 10X or more weight and cost of copper wiring. Installing and terminating this bulky copper to IT equipment cabinets is extremely expensive and impractical at power levels of greater than 20 kW per cabinet. For high voltage DC distribution, the copper use drops dramatically and is slightly lower than the best AC alternatives.

Overall, there is a slight equipment cost advantage for AC over low voltage DC for data center or network room power. Due to the low volumes associated with high voltage DC equipment there is currently no cost advantage over AC; however if high voltage DC were to become a standard, then it has the potential to have some equipment cost savings when compared with AC.

Compatibility

The use of DC for data center or network room power seriously limits the types of IT equipment that can be used. In most cases operation is not practical without adding a supplementary AC power system. If the potential application is for a standardized harmonized set of IT equipment such as a supercomputer installation, the compatibility problem is reduced.

Furthermore, in a high density installation, ASHRAE and various other organizations have demonstrated the need for uninterruptible operations of air conditioner fans. This means that during a power failure the air conditioner fans cannot wait for a generator to start and must be supplied with uninterrupted power. For an AC system, this is a simple wiring option. However, for a DC system this means that air conditioner fans compatible with external DC power must be used. Such devices are currently not available and are expected to be costly.

Reliability

Reliability comparisons between AC and DC power systems are highly dependent on the assumptions made. A DC power system is constructed of an array of DC rectifiers supplying one or more parallel battery strings. A number of recent UPS product introductions utilize a similar architecture with an array of UPS modules connected to a parallel array of battery strings. Due to their similarity, DC and AC systems using these designs can be directly compared. The result of such a comparison clearly indicates that the system reliability is controlled by the battery system. For a given life-cycle cost, it is possible to create a battery system for an AC UPS that exhibits the same reliability as a battery system for a DC plant. For an equivalent life-cycle cost, there is no clear reliability advantage of AC or DC for data center or network room power.

The above discussion suggests that for most users a move from AC to DC for data centers is not justified when efficiency, cost, compatibility and reliability are considered together. Of all the alternatives considered, high voltage DC does offer the best theoretical efficiency, but with significant compatibility issues. High voltage AC offers slightly lower efficiency but is universally compatible. For this reason it is a very practical approach to obtaining high efficiency.

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