

AC vs DC for Data Centers and Network Rooms

White Paper #63



Executive Summary

The use of DC power distribution as an alternative to AC in data centers and network rooms is uncommon. The considerations for the use of DC are described, and the reasons why AC will be the dominant choice for data center and network room power are explained.

Introduction

Power distribution to Information Technology equipment in a data center or network room can be accomplished using AC or DC power. AC power is typically distributed at the local mains voltage of 120V, 208V, or 230V. DC power is typically distributed at the telecommunications standard voltage of 48V.

Most installations use AC distribution. However, during the late 1990's, various manufacturers and engineers 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.

Many data center and network room operators appreciate and respect the high availability demonstrated by telephone system central offices, which have historically exhibited much higher availability than network rooms and data centers. Naturally there is a desire to duplicate this level of availability in commercial networks and an assumption that practices such as the use of DC have contributed to telephone system availability and should be copied.

Contrasting AC and DC

The considerations for the selection of AC vs. DC include the following elements:

- Efficiency
- Cost
- Compatibility
- Reliability

These factors are each discussed in the following sections

Efficiency

A principle argument put forth for the use of DC power in data centers is that it improves electrical efficiency. This is based on the idea that some steps of power conversion are eliminated, resulting in reduced losses. The losses in the 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 equipment.

The efficiency of AC UPS systems varies from 87% to 98% depending on model and load. The efficiency of DC power plants varies from 88% to 93%. AC UPSs and DC plants have comparable efficiencies, but the best AC UPSs have a higher efficiency than DC plants. AC UPS do typically have more conversion stages than DC plant, but they convert at higher voltage and reduced current where semiconductor efficiencies are higher.

To deliver the same power, distribution of DC voltage is done at currents approximately 4X higher than used for AC distribution. Distribution loss varies with the square of the current; therefore the size of copper used for DC distribution is 16X the copper used for AC for the same loss. Such severe oversizing is not typically implemented and instead additional losses are accepted. AC has the disadvantage that in some cases the AC voltage must be transformed, such as in some locations in North America where a transformer is used to convert 480V to 230V, whereas a DC plant can run directly from 480V. In these cases the AC distribution loss will be higher. However, in the vast majority of cases, AC distribution efficiency is higher.

A superficial review suggests that equipment using a DC input will be more efficient than using AC input, since it appears that some stages of power conversion are eliminated. This is not correct. In fact, all IT equipment using a DC input is designed to provide complete electrical isolation between the load and the DC plant; which is accomplished using power converters in the same way that this is done in an AC power supply. In fact, the DC input power supplies in IT equipment are less efficient than the AC versions because they operate at lower voltage and higher current. Measuring the power draw of the same piece of IT equipment configured for AC and then for DC, such as a router or server, demonstrates this fact.

There is no significant efficiency advantage of AC or DC for data center or network room power.

Cost

The cost of a DC power plant is typically lower than an AC UPS system by 10% to 30%. However, the additional engineering and 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.

There is no significant cost advantage of AC or DC for data center or network room power.

Compatibility

Circuit-switched telecommunications equipment, such as voice switches for copper wire, are almost all designed for DC use. Packet-switched telecommunications equipment, such as servers, storage, routers, etc. are almost all designed for AC use. The primary use of a facility will therefore dictate whether AC or DC will provide higher compatibility. The overwhelming use of packet-based equipment in network rooms and data centers suggests that compatibility will be much higher with an AC system. Obtaining DC versions of many products, such as monitors, NAS storage appliances, or PCs is virtually impossible.

The use of DC for data center or network room power seriously limits the types of equipment that can be used. In most cases operation is not practical without adding a supplementary AC power system.

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. A detailed comparison of various battery system arrangements is presented in APC White Paper #30: "Battery Technology for Data Centers and Network Rooms: Battery Options". 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 system.

For an equivalent life-cycle cost, there is no significant reliability advantage of AC or DC for data center or network room power.

Telephone central office reliability

Telephone central office availability is generally accepted to be one to two orders of magnitude superior to that achieved by commercial data center. However, this paper suggests that the use of DC in the central office is not a key factor in this performance. The improved performance of the central office requires an alternative explanation.

The data regarding down time for network rooms and data centers shows that the fundamental difference between network rooms and the telephone central office is the stability of the environment. Most data center down time is caused by human error. The average life of equipment in a data center is only two years, and configuration changes are happening on a continuous basis. The unforeseen consequences of the constant changes to the system, along with mistakes made while making changes, give rise to the vast majority of downtime.

The limited number of people with access to affect the system, and the structured and standardized nature of the system, are also key advantages in the telephone central office.

Of the factors related to the actual installation and design, the absence of a raised floor, the low power density, and the common use of convection cooling are fundamental reliability advantages of the central office.

Key imperatives for improvements in data center and network room availability include: systems to manage access, standardization of infrastructure, and monitoring and management systems; the use of AC or DC has minimal bearing on these issues.

Mixed-use facilities

Many data centers or network rooms have a small load or group of loads that require DC. In internet hosting sites, where a significant amount of telecommunications equipment is installed, the DC requirement

may be as much as 10% of the AC requirement. This leads to the question of how best to power these loads.

The recommended approach is to use small point-of-use DC battery-less rectifiers operating from the AC power system¹. In this approach small rack-mount rectifiers can be installed wherever and whenever a load requires DC. The need to maintain one or more DC battery plants is eliminated, along with the need to add or move DC wiring on a live system. In fact, no DC distribution planning is needed at all.

Conclusion

AC is displacing DC and will remain the dominant method for powering network rooms and data centers. There is no demonstrated advantage in cost, efficiency, or availability by using DC.

Network rooms and data centers will continue to be a heterogeneous mix of equipment. For many devices, such as monitors, AC powering is the only realistic option.

DC power remains the system of choice for circuit based networks, such as voice telephone networks. The flexibility and compatibility of AC power suggests that it will be the standard for powering packet-based networks such as modern network rooms and data centers.

¹ For more background on this approach, see “AC, DC or Hybrid Power Solutions For Today’s Telecommunications Facilities” by Gruz + Hall, Intelec 2000 conference proceedings.