APPLICATION NOTE

Data Center

DC in the Data Center — Already Here

Introduction

Various papers and articles have espoused the use of High Voltage DC (HVDC), typically 380VDC, for power distribution within a data center. However, the distribution of AC power within commercial buildings using 3 phase 480V AC is almost ubiquitous, and is the best understood by electricians tasked with its installation. The use of an AC UPS interrupts that distribution network to allow some battery backup to ensure the data center's continuous operation even during utility power interruptions.

Background

In the 1880s Thomas Edison and Nikola Tesla were prolific inventors working different aspects of electric currents. Edison experimented with Direct Current (DC) and used it in many inventions, including the light bulb and the phonograph. Direct Current sources, such as batteries and fuel cells provide power at a fixed voltage and changing DC to different voltages was difficult. Meanwhile Tesla had demonstrated some of the properties of Alternating Current (AC), and the ability to change the voltage using the magnetic properties in electrical transformers.

The magnetic properties were also used in Tesla's power generating equipment, used to power Chicago World's Fair in 1893 and the Niagara Falls Power Company's project to power all of Buffalo, New York.

Since then, most electricity generation and distribution has been AC at voltages from tens of volts to hundreds of thousands of volts (e.g. 110V indoors to 800KV on long distance power lines). The higher voltages result in lower losses over greater distances.

Advantages of DC

DC transmission efficiency

In low voltage short distance power transmission DC has no major advantage over AC, but at the grid level, over long distances (>hundreds of miles), DC transmission losses can be almost half that of AC (3.5% per 1,000 km, for DC, vs 6.5% for AC lines at the same voltage)[1]. High Voltage DC (HVDC) conversion equipment at the terminal stations is costly but can be more than offset by the reduced transmission losses if the distance is great enough. The primary contributors to the higher AC losses are skin effect and the influences of inductance and capacitance on virtual power compensation.

DC can be stored more readily than AC

As already mentioned, the chemistry of batteries lends itself to the storage and recovery of DC electrical power, which is important for operation of uninterruptible power supplies.

DC can now be converted from one voltage to another very efficiently

This has not always been the case. Early in the development of electrical power, AC found wide acceptance due to the availability of transformers to change the voltage of AC power. Developments of modern semiconductors and switching techniques now make the transformation of DC voltages as easy and efficient as AC transformers.

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Advantages of AC

AC has always been easy to convert from one voltage to another using transformers, this contributed to its early adoption in utility level distribution.

The availability of AC and its widespread adoption in industrial infrastructure makes it very attractive for installation and use.

The nature of AC is that its voltage is zero twice during each cycle, making current interruption simpler because any arc is "self-extinguishing". This makes safety devices smaller and less expensive at high voltages.

Voltage Levels (AC and DC)

Higher voltages result in lower currents for a given power level. Current travelling through conductors results in losses. The higher the current the higher the losses.

If elevating (eg doubling) the voltage, for a given power level, reduces the current by 50% the losses will be reduced by 75%[2]. This is true for both AC and DC resistive losses. Reactive losses only happen in AC circuits.

DC In Electronics and the Data Center

The transistor, the building block of most modern-day electronic circuitry, is a device that is used to control the flow of electricity, but generally only allows flow in a single direction, the essence of DC. Circuits using transistors can process ac signals, but they do so by operating in a specific range within the limits of DC used to power the circuit.

Internally, DC is used to power ALL servers, since they are made from integrated circuits that are comprised of many (thousands) of transistors, each used to control the flow of DC (binary) signals. The DC used to power servers is most often converted from an AC source by a power supply in each server or rack of servers. Many suppliers have optional power supply modules that can accept a DC input, most often at 48VDC as used for decades in the telecom industry.

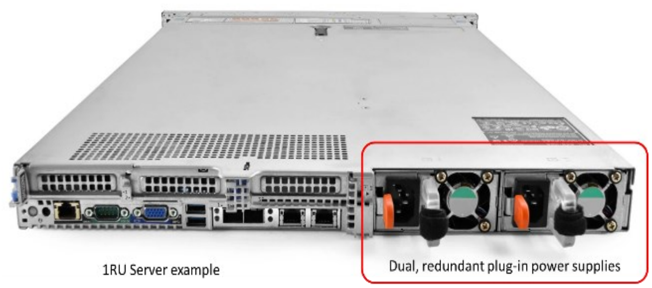

Figure 1 – Server, rear view

Powering Data Centers

The critical nature of many applications that are supported by large data centers, such as banking and life support functions, has made an Uninterruptible Power System (UPS) an essential part of the data center power supply. The UPS supports operations during a utility power interruption, usually for a long enough period of time for a reserve power source to be brought online (Generator, fuel cell etc). Depending on the reserve power source this may require several minutes of ride through power reserve.
UPS's can be configured to support AC or DC loads as will be discussed in the following sections.
DC is used in most energy storage locations, and all batteries because of the chemical reactions they use to store energy. This means that in an AC UPS power is converted to DC for battery storage and then back to AC for facility distribution. In a DC UPS the battery will be directly connected to the UPS output and hence the load.

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AC UPS Data Center Power

The voltages, DC use (red boxes), and approximate distances that power must travel are shown in Figure 2, for a typical data center facility using an AC UPS.

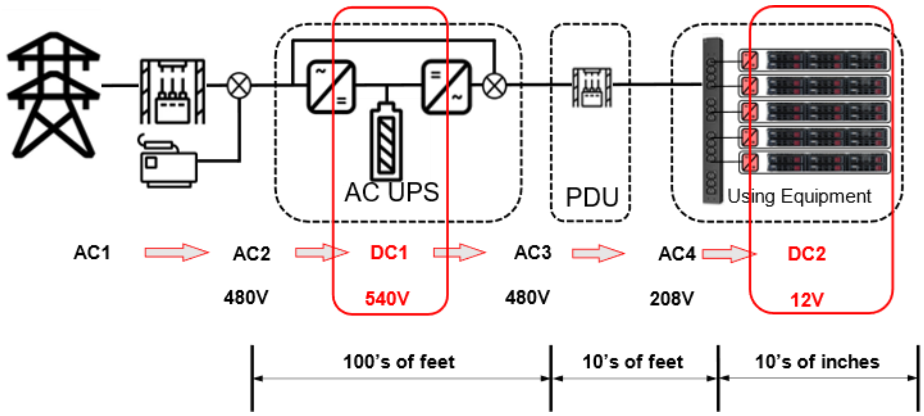

Figure 2 – Typical AC data center power architecture

Figure 2 also shows the types of voltage conversions that take place. Each red arrow indicates a change in voltage and / or type (AC or DC). In total there are 5 conversion steps. The red boxes indicate where the power is DC.

DC UPS in Telecom Data Centers

The traditional telecom data center has used a centralized 48VDC UPS with superb reliability for decades.

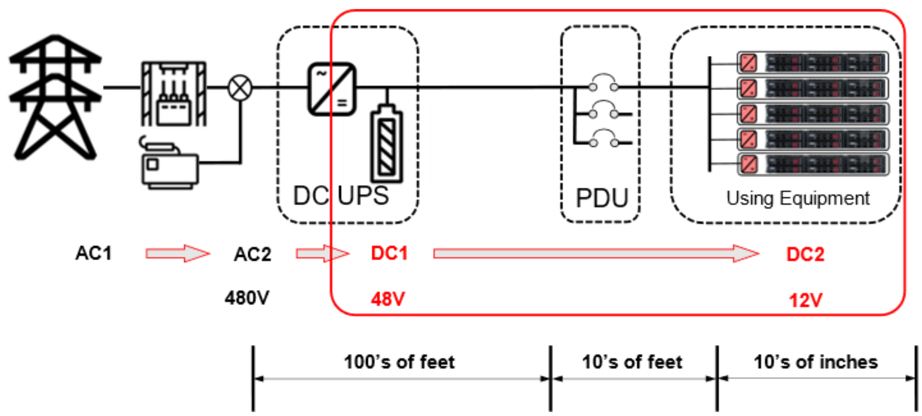

Figure 3 – Telecom data center power architecture

As can be seen in Figure 3, a large portion of the power architecture in the telecom application is now contained in the red box, indicating DC voltage.

Every time a power source is converted from AC to DC, from DC to AC, or from one voltage level to another a small loss is incurred due to the imperfect nature of power conversion techniques and materials. The telecom data center clearly has less conversion steps than an AC powered one.

High Voltage DC Power Architecture

A centralized, DC UPS can be made more efficient if the DC voltage is higher, losses will be reduced in the distribution, and the overall number of conversions remains low. This architecture requires protection and safety devices that operate at 380VDC, battery string(s) configured for 380V, and converters or power supplies at the load capable of accepting that input voltage.

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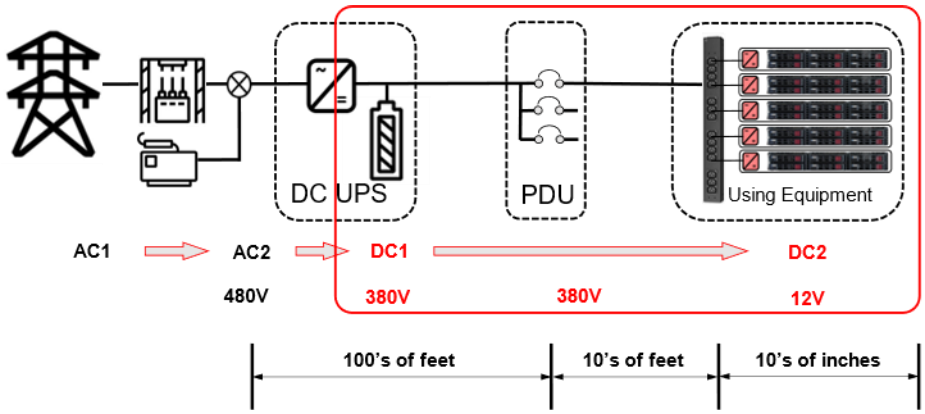

Figure 4 – High Voltage DC UPS data center power architecture

Figure 4 shows basically the same layout as the Telecom architecture shown in Figure 3, but now the transmission voltage is 380VDC in place of 48VDC.

AC or DC or Both – the Best of Both Worlds

Distributed DC Power Architecture

To minimize losses the power train needs to cover the larger distances at the highest voltage possible, and then minimize the number of conversions. The low transmission voltage is the downside to the telecom power architecture because significant distances still exist between a centralized power plant and the loads, and the voltage (48VDC) is relatively low. As shown in Figure 4, increasing the DC voltage can reduce the losses in the transmission section of the facility. There is another option.

Changing the centralized architecture to a distributed system can improve this considerably.

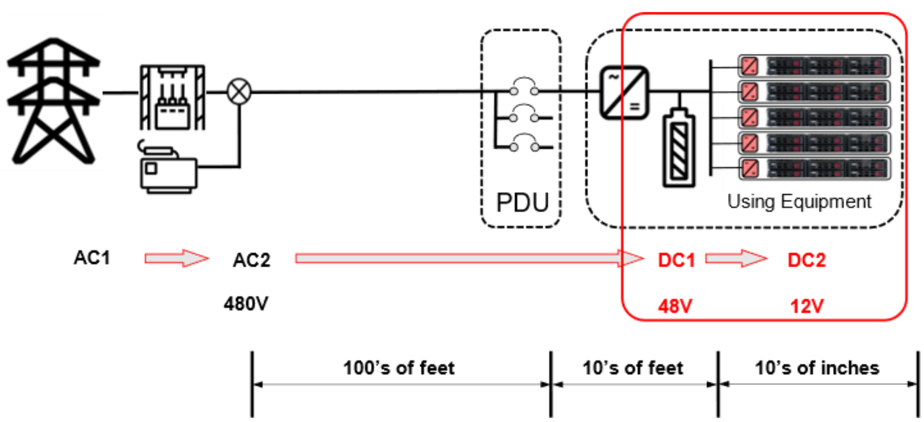

Figure 5 – Distributed DC UPS data center power architecture

By decentralizing the DC UPS and its battery backup, power transfer can happen at the higher, more efficient 480V AC, remain at 480V through the PDU, and finally get converted to low voltage DC in the load cabinet.

For this architecture to be complete the backup battery must also be situated in the load cabinet. Availability and industry acceptance of 48V battery backup units make this the voltage of choice for this kind of architecture.

When battery backup (for AC UPS or DC UPS) relies on flooded lead acid, there is justified concern about placing batteries containing gallons of acid alongside million-dollar data center processing equipment. Today, with the advent of sealed lead acid and other sealed battery chemistries, this concern is becoming moot.

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In a distributed DC UPS architecture, the battery is housed in the rack that it supports. Each battery will be commensurately small, when compared to the central battery backup. There will however be many more of them. This has the advantage of making battery maintenance simpler, since the batteries will be smaller, and in the case of intelligent batteries that self-identify with problems, timelier.

Summary

Battery backup in the data center UPS uses DC. The servers and storage functions of a data center are intrinsically DC operations, so DC is already here to stay in every data center.
Designing the backup power system to power a data center involves many factors to optimize efficient use of power. Conversion of AC to DC must occur at some point in the power train, and the choice of that point affects the number of conversions and the efficiency of power transmission.
The use of a distributed DC UPS offers advantages in efficiency by reducing the number of conversions and distributing power at the efficient 480VAC level. It also offers advantages in cost, maintenance and scalability if implemented correctly within the data center server cabinet. For more information on a Distributed DC UPS Power Architecture please see your OMNION POWER sales representative.

Footnotes:

1. "HVDC submarine power cables in the world : state-of-the-art knowledge" (PDF). *op.europa.eu. Publications Office of the European Union. 2017-04-28.* doi:10.2790/023689. Archived (PDF) *from the original on 2019-07-14*. Retrieved 2021-02-24.

2. 100W - 50V, 2A – losses ~I^2R = 4Units

   100W - 100V, 1A – losses ~I^2R = 1Units (75% reduction)

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