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DC Power

Charging up the Energy Debate

Features

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A Special Zerodowntime Report

DC for Data centers: Charging up the Energy Debate

The data center industry is currently in the midst of a major period of growth and transformation, and there is a widespread conviction that, this time round, it will be sustained. One only has to look at the supply crisis that exists in many locations around the world, a condition oft noted in DatacenterDynamics' own global conference series and by the testimonies of delegates and the number of contracts, announcements, sales of equipment, demand for qualified staff etc, which is regularly reported in the pages of ZDT, to see that this condition is more than anecdotal – it is rooted in fact and reality.

As the US EPA's Report to Congress on Server and Data center Energy Efficiency acknowledges, the increasing reliance on digital data in today's global society is driving a rapid increase in the number and size of data centers. This growth is the result of several factors, including growth in the use of internet media and communications, ongoing digital conversion of business applications, establishment of new regulations that require retention of digital records, and requirements related to disaster recovery.

As a result, data centers have become the infrastructure backbone for the world's economy. However, data centers require both high-quality and extremely reliable power, and although interest in energy efficiency has been growing as a solution to power and cooling problems in data centers, one of the main impediments to its adoption has been a perception that some energy-efficiency strategies may degrade data center performance or reliability.

Typical data center power delivery designs use AC (alternating current) power, distributed to the facility at 600V AC or 480V AC. This AC power is then stepped down to 208V AC or 120V AC for distribution to racks for use by servers and other information technology (IT) equipment. An UPS and energy storage system, such as batteries or flywheels is used to isolate equipment from power interruptions or other disturbances. This set up generally involves converting incoming AC power to DC (direct current) for energy storage. The DC power is then converted back to AC for the facility distribution grid and routed to power distribution units (PDUs) for distribution to equipment in racks.

Power supplies usually provide power factor correction as well as load isolation from the incoming power line for these sensitive electronic components. Thus, there can be up to six

or more power conversion stages between facility power entry and the microprocessor or other data processing circuits.

The power losses due to the use of inefficient power conversion devices from both outside and within equipment result in a large loss of useful electrical power, as well as directly increasing the energy required to remove the heat produced. Thus, for every watt of power utilized to process data, about 0.9W is required to support power conversion. In addition, about 0.6 to 1 watt will be required to cool the power conversion equipment.

According to a report 'DC Power for Improved Data center Efficiency', performed as part of Lawrence Berkeley National Laboratory's (LBNL) "High-Performance High-Tech Buildings" project focused on improving energy efficiency in laboratory, cleanroom, and data center facilities, power conversion efficiency for best-in-class computer grade AC-DC power supplies currently do not provide efficiency higher than about 90%. For servers, on-board non-isolated converters that provide final processor power conversion can range over 90% efficiency.

As LBNL and its consultants Ecos Consulting and EPRI Solutions recognize there have been many responses from the different sectors of the data center market to cope with this trend in rising power demand and drive for efficiency, including the utilization of direct current.

As the report notes, an optimal system might integrate the IT equipment with the facility in such a way as to minimize power conversions. The individual power supplies in servers could be eliminated, for example, if the correct voltages of DC power could be supplied efficiently from a central system, or in the case of fuel cells, directly from the power source.

Telco data centers have long been DC and are widely seen as the most reliable facilities in the world. However, there is a long-held industry recalcitrance regarding the implementation of direct current in the enterprise data center. Enterprise and service provider data centers have traditionally been built around a largely AC architecture. This is due to the fact that as they became the predominant facilities, they used of-the-shelf servers, all AC driven. Despite this, there is a growing exploration into the feasibility of implementing DC in the enterprise and service provider data center, especially supplying high voltage DC to servers. This body of research, demonstrations and proof of concept DC powered data centers are helping to overcome this reluctance, and show that DC is no longer a concept without reality.

1860

Transformer Invented

Historical Battleground

1880's

'War of Currents'

As is well-known, the dispute between Edison and Westinghouse decided the race for standards and left us with the only possible solution of power distribution as an alternating current system.

In the late 1880s, Thomas Edison and Nicholi Telsa fought a bitter campaign over the promotion of the competing DC and AC standards. The ensuing battle eventually became known as the 'War of Currents'.

For example, if low voltage is put it through a transformer the end result is high voltage AC. The advantage of high voltage AC is that it carries power with very little electric current, meaning that there is very little power loss in the wires, so power can be sent for long distances using long wires.

In this system, there would be no need to have electric generating plants in every neighborhood. When the electricity got close to a home, it could be transformed again, to convert the electricity to low voltage, which is less dangerous to use. A small transformer could be placed on the top of the pole that supported the wires.

1980-85

France Telecom
GEODE PROJECT
- high voltage DC
cabinet imagined but
modular decentralised
48V developed

Initially, direct current was the standard for the electricity distribution system of the US with DC used directly with storage batteries.

Direct current systems could be directly used with storage batteries, providing valuable load-levelling and backup power during interruptions of generator operation. From his work with rotary magnetic fields, Tesla devised a system for generation, transmission, and use of AC power. He partnered with George Westinghouse to commercialize this system. Westinghouse had previously bought the rights to Tesla's polyphase system patents and other patents for AC transformers from Lucien Gaulard and John Dixon Gibbs.

Today, we use a number of AC voltages and frequencies around the world that make up our present day power grids and that facilitate power to our homes, businesses, and of course our data and telecommunications centers.

1988

IEEE/Intelec HVDC
paper released by
Fujitsu

The method of producing power with generators, namely Tesla's poly phase motor, producing power at higher voltages and distributing it to the point of use then stepping it down to useable voltages, with Stanley's transformer, meant scalability, reduction of copper, less losses and most of all a much reduced voltage drop over long distances. Eventually, the debate went from philosophy, to proving which voltage was most dangerous, to the eventual conclusion of which method was the most economically feasible.

Initially, direct current was the standard for the electricity distribution system of the US with DC used directly with storage batteries.

1997

Intelec Advisory
Committee promotes
DC Power

Following the invention of the light bulb Edison wanted to electrify New York. His vision was to put metal wires on poles above the city streets, to carry current to every house. Because energy is lost in those wires (from their resistance), the energy could not be transported very far, and so to overcome this Edison envisaged placing an electric power generator in every neighbourhood, so that the wires would never be more than a few blocks long.

In the late 19th and the early part of the 20th century much of what was electrically powered consisted of lighting and motors and was operated on AC. Although in the last 50 years DC electronics has changed our lives and become the enabling technology and voltage that has allowed the reduction in size and cost of computation, communications and entertainment to name a few. Unfortunately, it has also become an insatiable driver of power demand. In fact, much, if not all of the electronic equipment we utilize to simplify our lives both at home and in our business life is in fact, at its core, DC.

2003

First Data center
DC- powered
equipment
commercially
available

In the meantime, a disgruntled Tesla who had previously been employed by Edison, had become enamoured with the idea of alternating current. In alternating current, the voltage and the current oscillate, positive and then negative and then positive again, 60 times every second. If AC was used instead of Edison's DC then it was possible to make use of the transformer – invented in 1860 by Antonio Pacinotti

However, as the DC circuits have reduced in size the demand on them to produce work with new and more powerful software functions continues to increase. As electronic devices have evolved, the overall systems demand more AC power to feed them therefore requiring larger, more complex emergency and backup equipment, larger and more robust distribution design, more transformations and of course rectifications to provide for the DC necessary to power the electronics at the board level.

2006

DC for data centres
working group
established

A transformer exploits the fact that a wire with current in it creates a magnetic field. If the current varies, then the magnetic field varies. A changing magnetic field will create a current in a second wire. The voltage in the second wire can be very different from the voltage in the first wire. What the transformer transforms is the voltage.

DC did not disappear. Due to the evolution of the battery, it instead became widely used and adopted as a standard in the telecommunications field.

2007

DC for data centres
workshop held

Today, all major telecommunications companies utilize 48 volts for distributing power to the communications equipment. Indeed, Sun, IBM, HP and others supply versions of their servers to the industry. 48VDC is considered both reliable and safe and accepted worldwide.

Research & Working groups

In 2006, a stakeholder group was formed by industry and the California Energy Commission to: investigate whether or not DC powered server(s) and/or server racks can provide the same level of functionality and computing performance when compared to similarly configured and operating servers (and/or server racks) containing AC powered server(s), as measured with industry standard measurement devices and software tools; to document any efficiency gains from the elimination of multiple conversion steps in the delivery of DC power; the feasibility for both facility-level as well as rack-level DC conversion and delivery, and identify issues/best practices and make recommendations for implementation.

The Berkeley Lab team of William Tschudi and Evan Mills, conceived the project and oversaw the demonstration's planning and design, which is being executed by private-sector firms ECOS Consulting and EPRI Solutions under a contract with Berkeley Lab. The partner companies provided technical advice, equipment, and staff to set up the demonstration at Sun Microsystems' Newark, California facility, which was open to interested parties from June through to August. The California Energy Commission's Public Interest Energy Research (PIER) program sponsored the project.

"We're excited to be able to demonstrate and evaluate the efficiency merits of two different data center DC-power-delivery approaches and expect our results can inform data center operators, facility designers, and this global industry regarding efficient options for future designs," says My Ton of ECOS Consulting.

The project participants also helped to define the three configurations for the demonstration project namely:

AC Reference Configuration:

This configuration is needed to simulate current data center typical set-up, delivering 208/120V AC input to AC-powered servers, and to be used as a reference to compare conversion efficiency.

Facility-Level DC Configuration:

This configuration is needed as the proof of concept – the ability to deliver high-voltage DC throughout the facility. This configuration handles the DC conversion/distribution at the building/data center level, converting 480V AC to 380V DC and delivering this directly to the DC-powered server units in the rack.

Rack-Level DC Configuration:

This configuration is needed to provide a possible migration option for AC data centers operators wishing to use DC equipment without facility-wide DC power distribution. This configuration accomplishes DC conversion/distribution at the rack level, using a rectifier unit to convert

208/120V AC at the rack, and delivering 380V DC to DC-powered servers.

In addition, a number of conditions were agreed upon by the participants and the project team on implementation, including:

Testing and Measurements:

The group agreed on test points and metrics, with emphasis on measuring the efficiency of the configurations – there would be no direct comparison of server equipment performance.

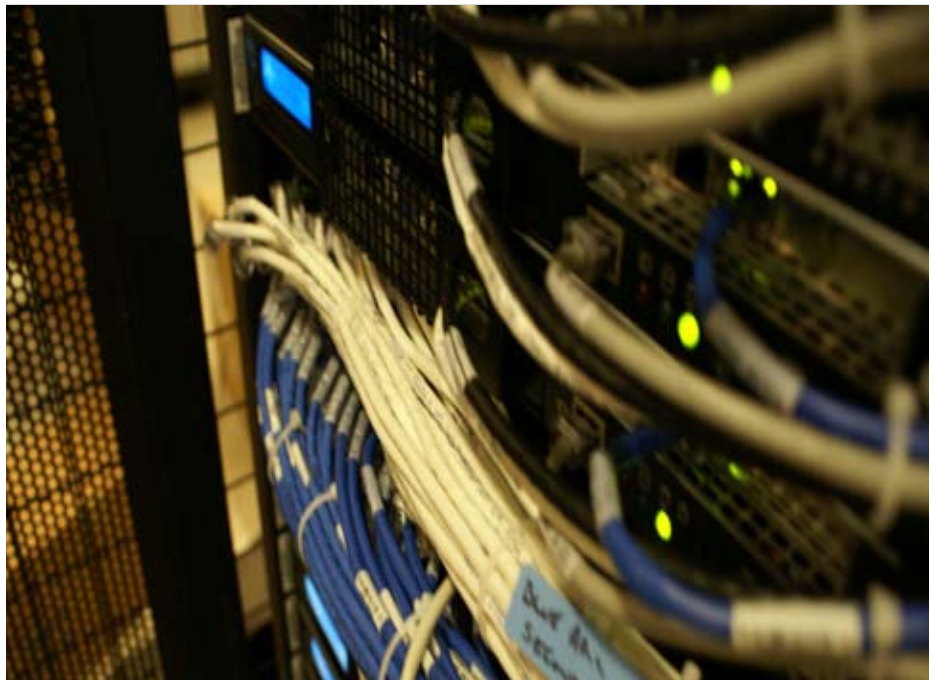
DC Input Voltage:

Due to compatibility with existing equipment and devices, the group settled on 380 V DC for the high voltage DC input.

The project implemented a power delivery system that distributes DC to the server racks.

The system used a single rectification stage, thereby removing the conventional UPS, transformer, and the rectifier in the server's first stage power supply. A standard AC distribution system is installed next to this DC system, server

The results indicate that the DC approach does provide an increase in conversion efficiency.



loads were connected and programmed to run identical routines. For this identical amount of computing work, the input power for whole system was measured and compared.

The results indicate that the DC approach does provide an increase in conversion efficiency. Access to two AC distribution systems as well as two DC conversion/distribution systems was possible and the efficiency ratios were determined for both sets.

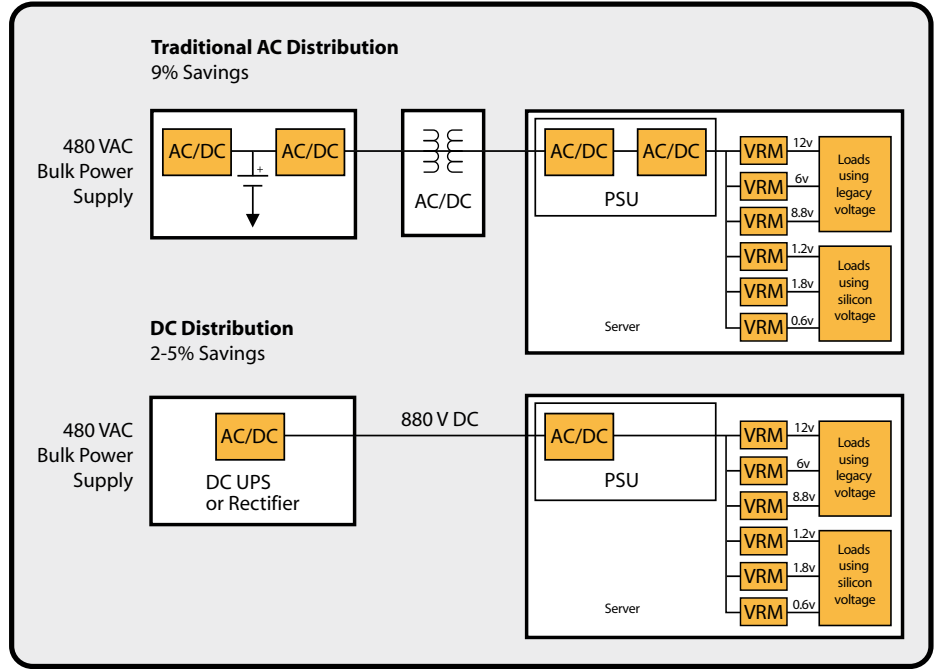
It was found that there was about a 7% decrease in input energy using the first DC system compared to the “best in class” AC systems. With the second DC system, the values are slightly lower, but still about 5% improved over the AC systems.

In its findings, the project notes that both of the AC distribution systems used represents the best on the market with regard to efficiency. Both of the AC UPSs are high efficiency units, and the efficiencies of the power supplies in the AC servers – at 90%, are much higher than units currently found in today’s data centers. By comparison, a typical AC system in today’s data center would have a UPS that was about 85% efficient, and power supplies around 73% efficient.

In this case, an improvement of over 28% is possible in an average data center. This means the DC distribution system, as demonstrated, will have the potential of using 28% less energy than the typical AC system found in today’s data centers. Since data center HVAC loads are typically about the same as the IT load, this means that a 28% improvement in distribution and conversion also means a 28% overall facility level efficiency improvement.

It should be noted that the magnitude of the DC efficiency gain is highly dependent on the AC reference system and AC/DC power supply that it is being compared to. However, exposing the industry to “best in class” systems may also be useful in bringing attention to the need for improving the average efficiency of data centers.

This demonstration project was able to coordinate the participation of 21 organizations, their equipment, and/or in kind contribution, worked with other organizations’ input throughout the implementation process, and assembled equipment and services worth over a million dollars in value. It was able to conclusively demonstrate to the data center industry (via



the 200+ open house attendees and the media coverage) that DC delivery systems are viable, can be 20% or more efficient than current AC delivery systems, be more reliable, and potentially cost less in the long run.

In particular the demonstration project showed that DC-powered servers exist in the same form factor as AC servers or can be built and operated from existing components with minimal effort. DC servers currently exist (in the 48V DC form factors), but 380V DC servers and storage equipment could be built and operated from existing components. Further, the demonstration project gave visibility to the DC power conversion and distribution equipment, highlighting two commercially available rectification systems, as well as UL-listed buss bars for DC applications.

The project also showed that DC-powered servers can provide the same level of functionality and computing performance when compared to similarly configured and operating servers containing AC power supplies. The demonstration equipment included storage units as well as DC network equipment that can use a variety of DC voltages.

In addition, the project demonstrated clear efficiency gains from the elimination of multiple conversion steps in the delivery of DC power to the server hardware. Results were measured

DC delivery systems are viable, can be 20% or more efficient than current AC delivery systems, be more reliable, and potentially cost less in the long run.

and documented from two sets of DC delivery systems, and compared to two sets of AC delivery systems. In both cases, the DC delivery system showed a minimum of 5% to 7% efficiency gains without significant optimization over two AC distribution systems that are “best in class” and much more efficient than most systems found in today’s data centers. These measured efficiency gains did not include additional gains from a reduction in cooling loads, which can have the potential for additional savings. Raising awareness of the AC - UPS system efficiency will have a benefit even if the DC solution is not embraced.

Proof of Concept

In 1997, the Intel Advisory Committee at their conference in Melbourne, Australia, called for studies regarding the option of powering computers using DC Power Plants. In response, a white paper 48VDC Computer Equipment Topology – An Emerging Technology’ was developed and presented. The white paper presented a very clear vision, and concluded: “We urge all end user and specifiers of Internet and data products to purchase and install DC fed equipment as a first choice. Such an approach will significantly increase the overall reliability.”

However, this did not materialize during the telecom boom, and it has taken a number of years for manufacturers to release what has long been known in the telecom industry.

There is now a small, but growing advocacy of DC power for data centers, helped in part by the availability of distributed DC power technologies for large-scale data center server deployments.

Today, with the significant maturity in the science of DC power electronics it is now feasible to produce redundant and reliable DC power systems, distribute it to the electronic loads in a scalable, effective, efficient manner, and feed DC electronics with DC power, thus leading to many intrinsic benefits. The main economic benefit is the reduction of the end-to-end power necessary to operate the electronic loads such as server type computers, lighting and even DC motors by up to 20% and potentially higher depending upon the server makeup and electrical design.

In 2003, the first distributed DC power technologies became available for large-scale enterprise and service provider data center server deployments. Long a standard in the telco industry, DC power options provide a more efficient power standard, eliminating the need for wasteful AC-DC power conversion inside a traditional AC power supply at the system level.

Rackable Systems claim that by replacing a standard AC power supply with a 93% efficient DC power card inside each server, power losses at the server level are instantly reduced. Instead of converting AC power to DC power inside the server, the conversion happens at the cabinet-level via redundant AC-to-DC rectifiers. By converting the power within the external rectifiers—which have an MTBF of 250,000 hours a piece—20-40% less heat is dissipated

within the servers themselves. The subsequent efficiency gain results in power savings while increasing overall system reliability.

In this rectified DC scenario, AC power is brought to the server cabinet through standard power distribution mechanisms. Rectifiers within the cabinet, which take up a mere 2U of rack space in a 44U cabinet populated with 80 systems mounted back-to-back, distribute redundant DC power to each system via DC bus bars housed inside the cabinet. Power savings of 10% and higher are achieved with rectified DC solutions, which can amount to millions of dollars in savings each year alone for a large-scale Web farm.

While the power savings achieved using DC solutions are certainly compelling, the real operational advantages are in the dramatic increase in system reliability. Higher MTBF in the DC power cards, coupled with a 20-40% reduction in heat inside the chassis, means higher uptime and reduced maintenance costs associated with system failure. Built-in redundancy at the cabinet level ensures system stability in the event of a power failure on a given circuit. And because rectified DC solutions can easily be deployed in any existing AC-based data center, no costly infrastructure changes are required.

Company officials say that 35 percent of the \$83 million in revenue the company generated in the fourth quarter of 2005 was related to DC power deployments.

The Validus DC system purports to have achieved the goals of reliability, affordability, redundancy and safety, and has integrated a system from the utility to the server that is completely DC. The integrated system starts with single or multiple rectifiers that can input any voltage and supply a distribution voltage of up to 575 volts DC (VDC) and can be designed inclusive an input filter required to attenuate reflected THD. This output bus of this rectifier mimics the voltage of UPS battery DC float voltage, maximizing the design and application of the battery string and battery run time in larger systems. This system as well as all of the DC electronics can be installed by qualified electricians much like today’s UPS battery systems. The rectifiers feed a fully coordinated 2N parallel distribution board, composed of breakers and diodes, that integrates the DC feeds, the energy storage, batteries, flywheels, photovoltaic or fuel cells. It can be applied in a main tie main scenario for

ease of A and B feeding and has a selection of output distribution for centralized converters on the data floor as well as essential cooling systems. The system utilizes a secondary converter that enables the voltage reduction to useable safe voltages (48VDC) right at or close to the load and is called the “PCU” (Power Converter Unit). This unit is also redundant in its power conversion path and has been utilized

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by the US Federal Government for some years in critical applications. The low voltage 48 DC feeds are fused and then sent to the computer rack where it can be brought together in a 2N arrangement utilizing diodes making it redundant very close to the computer. The computers can then be powered with highly reliable commercially used efficient 48VDC power supplies.

The system is extremely compatible with any DC storage system like batteries or flywheels and or renewable energy systems like fuel cells or photovoltaic. The system benefits are attributable to the minimum application of transformation, rectification and conversions by aggregating and optimizing central power supplies making the server voltage in only one rectification and one conversion. It is designed with the idea in mind that higher voltages are utilized at higher power levels isolating and compartmentalizing exposure to untrained personnel to contact dangerous voltage levels. The 48VDC is an acceptable safe voltage on the data floor where unskilled technicians have access, it is non frequency dependant and within the DC system produces no harmonics. It saves copper due to the higher distribution voltage and the physical nature of DC requiring less copper than AC for the same wattage. In light of the rising price of copper, and increase in the reported instances of copper

thefts from US buildings, this is an important consideration.

Both systems are currently in use around the world.

In 2003, Toshiba America Electronic Components Inc (TAEC), deployed distributed DC power-based clusters from Rackable Systems, at facilities in San Jose, California, and Marlborough, Massachusetts.

"Distributed DC power provided increased power efficiency that enabled us to populate our racks with highly customized systems — without heat concerns," said Richard Tobias, vice president of the ASIC and Foundry Business Unit of TAEC. "Since the DC power supply was substantially smaller than a traditional AC power supply, Rackable Systems provided exactly the right configuration and met our need to quickly deploy next generation EDA applications at a significantly lower acquisition cost. At the same time, we anticipate noticeable ongoing savings in two areas. As each system uses fewer watts, leading to cooler clusters, our IT staff will spend less time responding to failed systems, replacing heat-worn components and reacting to other downtime crises. We also expect much lower costs in terms of our monthly electricity bill."

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In the UK, dedicated hosting solutions provider, Ultraspeed, has recently adopted DC power, based on a solution from Rackable Systems, as part of a wider blend of measures to deliver a next generation hosting service that cuts energy consumption by 40%.

Jordan Gross, commercial director at Ultraspeed comments: "It's time for the IT industry to recognise that additional features and functionality in a

managed hosting environment can be achieved in parallel with a substantial reduction in the associated carbon footprint. The inherent stability and efficiency of DC power has been known for years yet very few companies operating large server farms actually use it. With a potential reduction in overall carbon emissions from that initiative alone of around 30%, this is inexcusable."

Gross also explains the crucial commercial drivers placed on large IT energy users: "Modern servers are smaller but draw three times more power than their 1990s equivalents. Data centers were simply not designed to handle that sort of consumption and many now need a separate substation to be built (which is often not possible) in order to increase server space. This naturally pushes the price up for businesses. Switching to lower energy technology is therefore an imperative not just for the environment but is also needed for UK businesses to remain competitive."

According to Tschudi, if data centers were powered by DC, there would be no need for so many conversions. In addition, it would increase the viability of using distributed renewables that generate DC power at these facilities.

"If there were wider adoption of this technology it would be easy to integrate other renewable sources into the distribution scheme. If it were easy to switch between a PV source and the grid without any additional conversion losses, that would be very attractive," said Tschudi.

Based in California, Affordable Internet Services Online (AISO) operates its own green data center and network powered entirely by solar panels.

Power is generated using 120 solar panels located on two large sets of arrays, one on each side of the data center, capable of generating up to sixty kilowatt-hours of electricity daily. The solar panel arrays face due south, which will generate the most possible amount of electricity. The power from the solar panels is DC, which is converted to AC through a sunny boy inverter. After it is converted using the inverters it is stored in a battery bank. It then leaves the battery bank and runs throughout the data center and offices including the air conditioners. In case of an emergency power can be sourced from a backup generator. A large UPS system also provides power backup and conditions the power supply protecting equipment from voltage fluctuations and spikes.

Lighting during the day is provided by the use of solar tubes, which bring in the outside light.

Barriers to adoption

However, despite these early adopters, Tschudi cautions of significant concerns including the lack of industry knowledge of the advantages of DC distribution, as well as misconceptions about DC power. Additional education and outreach efforts will be required if the energy savings potentials of DC powered data centers are to be realized.

Tschudi et al highlight the lack of a single, trusted source of information, or an entity dedicated to the promotion of data center energy-efficiency and DC distribution (other than the CEC/PIER efforts). With the current industry support and interest, a "DC Power" association of some sort will help to focus interest and help to elevate awareness among the data center market.

They also argue that agreement on distribution voltages, electrical connectors, grounding, DC power quality, and other issues will be important to enable the market to adopt DC distribution on a large scale.

As a point in case, in December 2006, United Airlines announced it was considering implementing a DC data center in Denver, to consolidate disaster recovery operations.

However, a number of concerns were quickly posited. These included DC-compatibility issues with hardware and having a single DC-power input.

Tom Songaila, manager of data center planning and business resumption for United, also reported the expense of DC servers and DC UPS as a potential prohibitive factor in the decision. More importantly, he also encountered an inability to secure DC storage hardware – a necessary building block for the DC project to be realized.

Cited in a recent IT Week article, Ed Ansett, EYP Mission Critical Facilities comments on the debate. 'People are dismissive of DC because they are unfamiliar with it. Most people in the UPS world do not know much about DC, and

vice versa. There is not much empathy on either side but I think that will change.

I expect to see the first commercially operating data center based on DC power rolled out in the telecoms world within the next 12 months, with other industries following once the technology is proven.'

But can DC really be accepted in the enterprise and service provider facility?

'People are dismissive of DC because they are unfamiliar with it.

One immediate obstacle to this acceptance is the lack of available electricians with the experience of working with DC power. Those with the necessary skill sets predominately work in the railroad or smelting industries, or are approaching retirement having worked in telco facilities. There is a dirge of qualified and available electrical engineers able to work with DC powered data centers. This extends to training and certification of personnel working inside the racks and training and certification of personnel installing building power distribution

Concerns also exist over the availability of Underwriters Laboratory (UL)-rated equipment. Installations of electrical equipment rated over 600 volts that are managed by premises or equipment owners and not the supplying utility are growing rapidly. As a result, equipment rated over 600 volts is increasingly becoming subject to the requirements of the NEC in the US or CEC in Canada, local ordinances and local code authorities.

There are also huge concerns over the safety involved in disconnecting DC plugs, and the efficiency of distributing higher (60VDC) voltage to the data center. As is widely known, 48VDC is safe and used throughout every data center

at present. But when the power is fed from the transformers to the PDUs, and then from the main PDUs to row level PDUs, this feed will be above 60VDC. Above this rating damage to equipment, personal injury and death can occur. Special precautions must be adhered to when voltages in excess of 60VDC.

Furthermore, users and vendors are still to settle on a worldwide standard on voltage as well standardizing DC connectors, which could overcome the problem of accidental arc-flash.

But are these proactive and dissenting voices simply reactivating the historical AC-DC War of Currents, or can DC really enjoy a renaissance? As Sun Microsystems comments, will the single digit efficiency improvements justify the adaptation of a new infrastructure? Double-digit savings can easily be achieved through virtualization or the use of air-side economizers for example.

As Randhir Malik, IBM states, IBM uses 350V DC at rack level and over the years have found that using 350V DC over the whole data center is more costly than at a Rack level. There are other issues such as the equipment that operate on AC which makes a big issue for adoption. IBM currently uses 480/230V AC three phase coming to the rack without any need of extra PDU.

However, the ongoing discussion is what a high voltage DC buys us that a solution at rack level or multiple rack level is not providing us.

It is clear that more questions need to be answered to convince the antipathetic that DC is safe, reliable and suitable to enterprise data centers. Through the collaborative efforts of the various DC working groups, the product releases from OEMs and the desire for greater energy efficiency across all data centers, DC advocacy is growing.

Whilst the industry cannot change over night, a step change is gradually taking place and DC power cannot be ignored.

Article Information

In compiling this special feature, our thanks go to the following who have kindly supplied editorial and allowed the inclusion of abridged articles to be used:

Rudy Kraus, CEO Validus DC Systems for providing a succinct historical overview of the AC-DC war and for technological information regarding commercial DC products.

Kraus has been an active participant in recent DC workshops including being a panelist and speaker at the LBNL DC Power Partners Meeting.

William Tschudi, a leading coordinator of the LBNL DC working group, and Jordan Gross, of Ultraspeed for provisioning us with details of the hosting company's recent experiences of DC in its London facility.