380 Vdc for the Modern Data Center

THE BENEFITS OF dc – Summary Document

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DC-NEXUS
THE DIRECT CURRENT CONNECTION

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THE BENEFITS OF dc

THE BUSINESS CASE TO CHANGE

The realization that there is an undeniable business case in favor of 380v dc power is happening but before wide scale acceptance and deployment can/will begin, the benefits of dc must be presented. The benefits must be so compelling that lack of action to the conversion from ac to dc would be thought of as an unwise business decision as new data centers are built or existing data centers are renovated. This is the exact process that was experienced many years ago when ac power finally won as the topology of choice – BUT IN REVERSE!

A data center person can readily and intuitively design, adapt, and optimize power from the perspective of the chip towards the power grid. And yet tradition has been just the opposite. The unique concept of ***Chip2Grid™*** technology captures the power design from the chip's perspective. Looking back from the chip, the internal power supply distribution for computers begins at 380V dc, therefore all IT power supplies can easily migrate to this solution. Since the existing grid is an ac source, the voltage type must be changed to dc only once (half a typical UPS system) rather than multiple conversions back and forth performed by legacy ac UPS and data center power system architectures. Better yet, if the power grid or source is already dc, there is no need to change it back & forth at all. An example would be to power a computer directly from solar or the dc output point of a fuel cell. The power supply for the server would not have to change ac to dc. Power supply providers who manufacture for over 70% of servers globally embrace this technology.

Today's ac industry focuses too much attention on the efficiency gains, (or lack there-of), when transitioning to a dc infrastructure topology. This paper focuses on the multiple engineering issues and ideas that will make dc power the power topology of the future because the future benefits will be shown to be too compelling to think otherwise.

This paper focuses on three distinct areas:

1. How to invest more in your core business systems and reduce the non-core (facility) expenditures.
2. The positive realities of components available now in 380V dc.
3. Dc Power Topology of the 380V dc infrastructure. Key issued addressed include: power supply details; connectors; conductors, wire and cords; power distribution units/PDUs; branch circuit protection; metering; busway; distribution level circuit protection and control; grounding; load balancing; equipment space; reliability; short circuit and arc flash protection; voltage drop; dc motors and control; dc lighting and cross industry collaboration.

Every data center stakeholder, from the operations staff to the Chief Financial Officer, will benefit from a ***Chip2Grid™*** contribution to data center operations and the improved bottom-line it yields. Consider these BENEFITS OF dc:

Effect on Data Center	***Chip2Grid™*** Attribute	Benefit
Data Center Reliability	Higher Reliability	200 to 1000% increase in reliability due to fewer points of failure & flexible energy storage integration.
Funds Reduction #1	Lower capital cost & modularity	Capital costs of electrical facility reduced by 15% or more. First cost can be farther minimized by adding plug-and-play modules as capacity needs increase
Funds Reduction #2	Lower O&M	On average the operation and maintenance costs will be reduced by 33% or more than AC data center power systems.
Funds Reduction #3	Smaller Footprint	With a 35% space savings in the electrical infrastructure, a whole variety of savings are received, could include the avoidance of physical building expansion.
Convert Now	Easier Data Center Conversions	When changing to a new and innovative technology usually a "rip & replace" approach is needed. With ***Chip2Grid™*** a phased "swap out" at your pace making decision making and planning easier.
Use Renewables	Easier Integration of Renewable Energy	Most renewables are inherently dc -Wind, Solar -Energy Storage -Fuel Cell
Efficiency #1	Higher Efficiency System	Start with an inherent energy savings and work for more.
Efficiency #2	Lower Heat Load	Overall heat load of this technology is less.

THE BENEFITS OF dc AS RELATED TO COMPONENTS

Components involved and aspects of electrical design engineering with 380V dc technology illustrate some of the positive realities of this approach.

IT power supplies	Power supplies accept 380V dc input and uses what has been shown to be an optimal voltage level. The bus can be center tap high resistance grounded (+/- 190 dc) to further reduce any hazards. 380V dc distribution leads to additional advances in power supply efficiencies.
Universal 380V dc	380V dc is universal. For existing power supplies not currently at 380V dc all that is required is an off-the-shelf receptacle and elimination of ac power conversion components. 380V dc has world-wide/international acceptance and standardization
Safety connectors to the servers	Breaking arc, if present, in the connector is fully extinguished before opening of the connector and passes UL jointed test finger proof tests. Other technologies exist to make sure circuits are not energized when breaking and making connections
Power Distribution System	380V DC allows for more power delivery than ac on the same amount of copper.
Rack mount PDU's	New connector designs offer enhanced reliability. 380V dc offers more power per PDU with less wires and less copper.
Modularity	Modularity not previously available allows easier design and installation. Enhanced plug-and-play availability.
380V dc UPS	No need to do an ac-dc conversion followed by a dc-ac conversion. Shorter path with higher efficiency and higher reliability.
Load balancing	Load balancing is not required for 380V dc, BUT is becoming a bigger issue for ac.
System overload, short circuit and arc flash protection	380V dc offers new opportunities for new circuit protection technologies with the potential of providing for safer systems. As ac data center distribution moves to higher voltages (400V ac, 415V ac, 480V ac) arc flash and circuit protection at the rack becomes a bigger safety issue in ac systems.

Temperature – heat!	Dc systems operate inherently cooler and at the same to hydraulic-magnetic circuit breaker are not subject to de-rating at higher operating temperatures
Server fans	Can run off 380V dc and inherently provide a reduction in power consumption with simpler and more precise control.
Cooling systems	Cooling systems can also utilize 380V dc motors providing inherent benefits of the infrastructure to the cooling system.
Harmonics	Harmonics can be treated at the dc source thus allowing for the elimination of filtering at the component level.
Traditional or Green Power Grid	Sources such as wind, solar, batteries are already dc and by removing the ac conversion there is improved efficiency and return on investment.
Dc microgrids	Another advantage of dc power is the potential of creating dc micro-grids. A dc micro-grid is more conducive to the integration of alternative energy sources with traditional energy sources for on-grid and islanding mode operation. Micro grids can support traditional ac loads AND new dc loads at the same time.
Paralleling and Synchronization	Combining ac sources required active paralleling with sophisticated controls and metering – combining dc sources require only voltage parity within and between systems

OPERATIONS, MAINTENANCE AND SAFETY OF 380V dc SYSTEMS

Operations and Maintenance:

Data Centers are typically a more complex facility to operate and maintain. Power and cooling systems are required to operate continuously with high reliability and maintainability in order to meet the 7x24 on-line requirements for the computer and communications systems within. As such, most data centers are staffed by a full time, around-the-clock staff to monitor and maintain the building systems. As load densities have increased and as data centers have increased in size the associated power and cooling systems have also become larger and more complex. It is often quoted that human error is the cause of most data center outages and failures. One way to reduce errors is to make the systems simpler and reduce the number of components within these systems. 380V dc power allows just that. Reduced system components mean higher reliability and lower operations and maintenance costs. 380V dc allows for a simpler power system building block topology. Many of the engineering details, which are described earlier, contribute to this fact.

Safety:

High reliability is the number one requirement for Data Center operations. Implicit to this reliability requirement is that electrical systems must also be safe. It is also understood and agreed that electricity, at the voltages and power levels associated with data centers, can be hazardous to individuals exposed to live parts. There are primarily two aspects of electrical safety hazards that one has to keep in mind, arc flash, and electrocution. The first is related to the exposure of a human body to the arc as the source of intense heat causing burns and other severe injury. The second is related to direct contact with the live energize parts causing the electrical current to flow through a human body. As such the following is a list of issues regarding safety of 380V dc versus ac power topologies:

- Both ac and dc systems are engineered safely using properly rated and certified equipment that has been tested for safety.
- Electricity is a hazard. ac and dc systems are designed and rated to eliminate exposure to this hazard. Unsafe operations of ac or dc systems are equally hazardous. Work on the systems is typically allowed only when de-energized.
- UL rated or equivalent dc connectors for hot connect/disconnect of IT equipment exist and new form factors are in development and testing. The Green Grid [7] acknowledges that work around dc powered equipment should not be a problem.
- dc operational experience from other industries is at least as safe as ac operational experience.
- Overcurrent protective devices have an impact on the two most important variables of arc flash hazards:
  - Time (speed of the OCPD)
  - Fault current magnitude (current-limitation may help reduce)
- Fault Current Limitation (FCL) may be able to significantly reduce the energy released during arcing faults. Power and load flow control will be easier and more exact in dc systems primarily due to power electronics.
- As ac voltage levels are increasing in data centers, (400/230VAC, 415/240VAC, 480/277VAC (rms voltages)), so does arc flash exposure to the personnel working with IT racks and servers.
- New technologies are available for dc circuit protection which are faster and more exact than ac circuit protection. Faster and more exact protection will contribute to higher safety.

CONCLUSION AND FUTURE TRENDS

The required DC topology is available now. The financial, reliability, real estate, and adaptability reasons to shift are compelling. For data centers the Chip2Grid™ technology standard is established. It simply is a matter of shifting your attention and money to the output of the data center.

Chip2Grid Technology has powerful benefits using currently available technologies and with great potentials for new technologies to address power consumption, real estate, cost & expense reduction, increased focus on the chip, reduced real estate, and easy green power integration. Plus you get increased efficiency as part of the package.