Mission Critical Power: Past, Present and Future

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Eaton is a leading **power management company**

We help the world use electrical, fluid and mechanical power more **reliably**, **efficiently**, **safely** and **sustainably**.

Vehicle – Aerospace – Hydraulics – Electrical Products – Electrical Systems & Services
Electrical Sector
Solutions for the entire power system

- IT and data centers
- Oil and gas, mining, industrial
- Electric utility
- Commercial
- Institutional
- Government
- Alternative energy
- Residential

Power distribution and circuit protection
Backup power protection
Lighting and security
Control and automation
Structural and wiring devices
Solutions for harsh and hazardous environments
Engineering services
Eaton’s Electrical Sector: Global reach, local depth

- Customers in more than 175 countries
- Thousands of engineers and service personnel
- More than 7,500 sales and marketing professionals
- Distributors in more than 12,000 locations
Our Dependence on Reliable Power...

Nothing Works…
Nothing Communicates
Nothing Moves…

... Without Reliable Electrical Power!

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Industrial Economy  
Digital Economy  
Services Economy

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The "traditional nine" Power Problems

### Customer Needs
- **SWITCHING TRANSIENTS**
- **HARMONIC DISTORTION**
- **POWER FAILURE**
- **UNDER VOLTAGE**
- **POWER SAG**
- **OVER VOLTAGE**
- **POWER SURGE**

### Equipment Protection
- **Surge Protection, Electrical Distribution**
- **Transformers, Filters, Voltage Regulators**
- **UPS, DC Plant, with back-up generator**

### Equipment Operation
- **Redundant UPS or DC Systems with Back-up generators regularly monitored and maintained**

### Process Protection
- **Availability [Downtime per year]**
  - Two nines (99%) [315360s (or 87.6h)]
  - Three nines (99.9%) [31536s (or 8.76h)]
  - Four nines (99.99%) [3153.6 (or 52.56m)]
  - Five nines (99.999%) [315.36s (or 5.256m)]
  - Six nines 99.9999% [31.5 seconds]
  - Seven nines 99.99999% [3.15 seconds]

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Traditional double-conversion UPS

**Double-conversion UPS**
- Conditions the input power and provides stable voltage and frequency to the critical load.
- Rectifier converts AC to DC, stores energy in the battery, and the Inverter converts DC back to clean AC power.

**Battery**
- Battery bank provides backup for orderly shutdown, generator start or continued operation in case of power failure.

**Manual Bypass**
- Power path to critical load during scheduled maintenance.

**Static Bypass**
- Redundant power path for increased power reliability.

**From Utility Grid**
- AC from Utility Grid to UPS.

**To Critical Load**
- AC from Inverter to Critical Load.

**Graphical Representation**
- Rectifier converts AC to DC.
- Battery stores energy in DC.
- Inverter converts DC back to clean AC.
- UPS provides stable voltage and frequency to the critical load.
- Manual Bypass and Static Bypass provide redundant power paths.
State-of-the-art double-conversion UPS

- Transformer-less topologies with double conversion efficiencies reaching 97% with use of three-level converters and advanced digital signal processing
- High-frequency power conversion continues to increase power density
- Modular designs, allowing for N+1 redundant operation at partial loads
- Flexible thermal management becoming increasingly more important
The Key Challenge

Energy Efficiency

- Reduce Operating Expenses
- Address Sustainability Concerns
- Comply with changing regulations

In today’s data centers…

- Underutilized assets – Power infrastructure costs are very high, typically oversized and never fully utilized. Stranded power and cooling capacity.
- Excessive energy losses - Operating costs are higher than they need to be.
- IT, power and cooling devices show partial interoperability aimed to monitoring and control

Currently advances on different fronts…

- IT Virtualization and resiliency in software layers starting to reduce dependency on redundant power and hardware
- Increasing the efficiency of the power and cooling delivery chains
Further Addressing Efficiency Concerns

A historical view of IT equipment tolerance to power disturbances
Energy Saving Architectures

Transformer-less topologies and digital signal processing enables 99% efficient power protection for critical loads

"in series" power processing is replaced by "on-demand parallel processing", including load harmonic cancellation and power factor correction
Energy Saving Architectures

Advances in digital signal processing and computational power will continue to improve “eco” modes of operation.

Critical load protection of advanced “eco” topologies compared to double-conversion will be proven.

Energy saving architectures will become mainstream.
DC Distribution Alternatives

- Previous studies and demonstrations claimed a wide range of efficiency gains for 380VDC systems - our studies show only 1% - 2% more efficient than state-of-the-art AC double conversion, and 1% less efficient than AC energy saving architectures. Power conversion efficiency no longer a major argument.
- Arguments for 380VDC distribution today are reliability and cost. Cost of copper wiring and distribution losses need to be also considered.
- DC installations have a limitation of short circuit current values, and are more difficult to protect against with regards to electrical shock and arc flash.
- There is room for 380VDC distribution within a rack, or maybe in adjacent pieces of equipment within a "row".

![Diagram of DC Distribution System]
The Future of Information Technology

- Critical dependency on IT application services and 24 hour x 7 day application availability expectations
- “Big Data” – huge amounts of data requiring more storage infrastructure
- Analytics – Turning data into information for decision-making; requires significant server / storage / application infrastructure
- Explosion in Mobile Computing – need to access to applications and data with reliable performance
- Cloud Services – Public and private
- Explosion of social networking and HD video
- “Pervasive Computing” – Everything is becoming chip enabled
- Network equipment is expected to handle more traffic and reduce power consumption
And the demands on future data center power delivery chains

Reduce TCO (‘total cost of ownership’)
- Higher efficiency
- Higher operating temperatures
- Use of "free cooling" in environments that have been traditionally "air conditioned"

Flexible power architectures
- Dynamic power delivery topologies balancing availability, efficiency
- Operating from multiple power sources, including renewables
- Utilizing wide array of energy storage options

Reduce system complexity
- "Fear of failure" has been driving complex (and costly) system architectures
- Resiliency is now included in applications, software
- Customers recognize they have to plan for failure
Technical advances continuing to shape the industry

• Wide bandgap semiconductors and advanced magnetics design resulting in higher efficiency power conversion - but need lower cost options

• Faster DSP processors and increased computational bandwidth further enabling advanced algorithms - "embedded software content" overcoming "hardware content"

• Applications of "big data" to a variety of areas like power system analytics and power electronics components life estimation
Robustness and Resiliency

- **Design for Resiliency** - System design needs to include failure modes and effects analysis at every level - it is very important to understand "how things fail" as well as "how things work"

- Power Electronics Design - needs to consider variance and tools like Monte Carlo simulation - set the expectation on components suppliers that modeling of variance is an expected deliverable

- DSP Controls and Algorithms - consider robust methods to ensure predictability under all circumstances - state machine modeling, DFMEA on software

Use of "Design for Six Sigma" concepts and tools ensures robust and resilient designs that meet mission critical power industry expectations
Safety and Sustainability

Environmental Responsibility

Globalization...
... and local regulations

Reduction of Hazardous Substances (RoHS)

Must Reduce CO$_2$ By 2X

Increased Safety Awareness
Questions