


Modular and Scalable Power Converters in the UPS Industry

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Content

- Eaton Overview
- Eaton Electric – UPS Business
- Today's Critical Power Systems
- UPS Market Drivers
- Modern UPS converter technology
 - Design for reliability
 - Scalability & Redundant Systems for high 9's reliability
 - Topology and control
- Modularity : Power Control
 - Two examples:
 - 9390 UPS power / control structure
 - Blade UPS modularity / power density.



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Eaton Overview

Electrical



Fluid Power



Automotive



Truck



- A global diversified industrial manufacturer
 - 2005 sales: \$11.1 billion
- A leader in:
 - **Electrical power quality and control**
 - Fluid power systems
 - Automotive engine air management
 - Intelligent drivetrain and safety systems for trucks & heavy vehicles



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What Markets Does Eaton Serve?



**Industrial Facilities
& Utilities**



Residential

Telecom / Data Centers



Commercial/Institutional Facility



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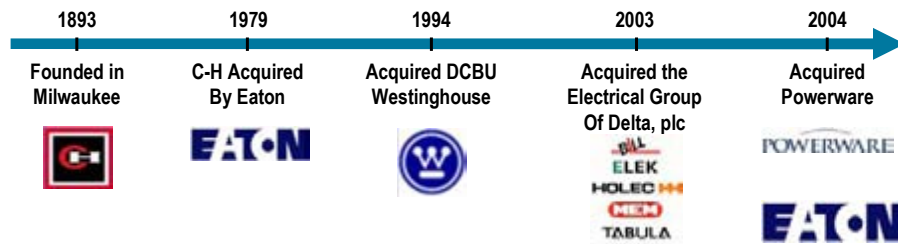
Eaton Business Segment – Electrical

\$3.7 billion sales in 2005.

14,000 employees, 57 factories in 19 countries

→ electrical control, power distribution, UPS, industrial automation products & services, ...

- [Power Quality Systems](#)
- [Power Component & Systems](#)
- [Electrical Components / Industrial Control](#)



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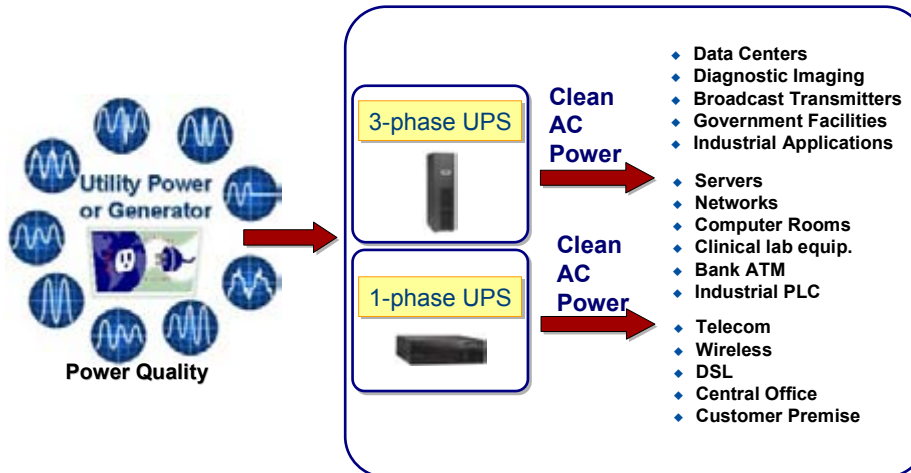
Eaton Electrical – Power Quality Systems

- Mission Critical UPS systems for highest power reliability (emergency back-up)
- Single phase & three phase UPS Modular, transformerless up to 160 kVA
- Industrial & Rack-mount UPS
- Sag Ride-through Power Conditioner
- Active and Passive Harmonic Filters
- Static Transfer Switches
- Advanced Battery Management
- Integration & Global Service Support



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UPS Systems – Key to 24/7 Daily Life



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Eaton UPS Market Position

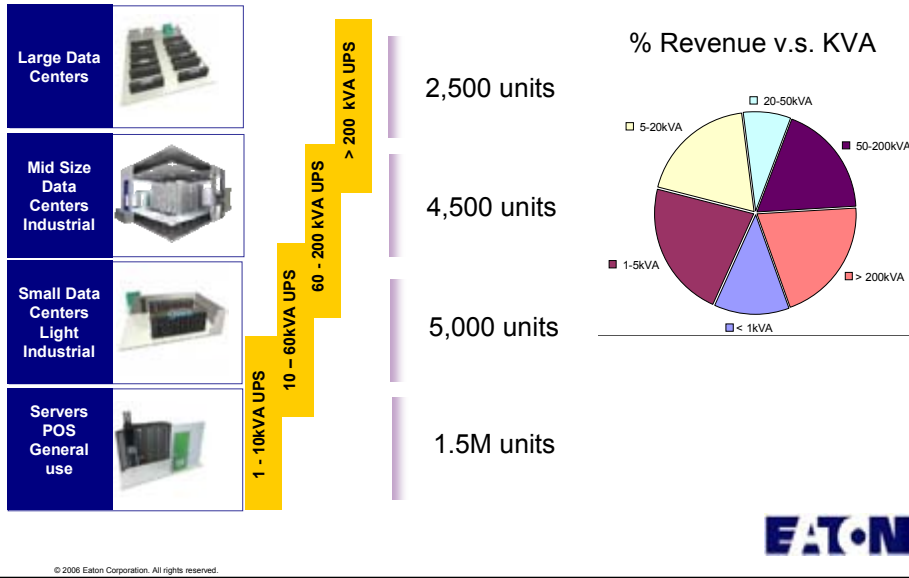
- Eaton is an industry leader and globally recognized provider of innovative, effective power quality solutions, delivered under the Powerware brand
 - Power protection revenue ~ \$900M
 - #1 in worldwide UPS sales above 5 kVA
 - #2 in worldwide UPS sales at and under 5 kVA
 - Total volume: >1.5 million units / year
 - 3-Phase volume: ~ 7,000 3-phase units / year
 - Large installed base of more than 45,000 3-phase UPSs worldwide

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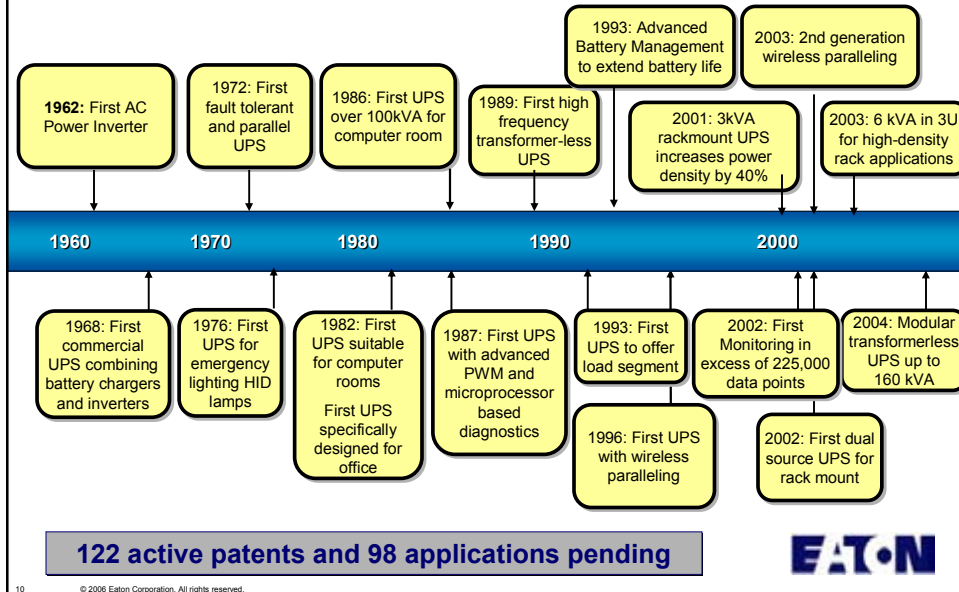
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Eaton UPS Market Position



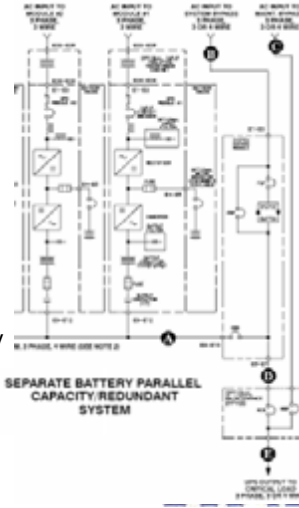
Eaton UPS Technology Leadership



Today's Critical Power Systems

- Main elements of Critical Power systems
Measured by 9's of availability

- Multi-source / storage systems
 - Utility (single / multiple feeds)
 - DC Batteries
 - AC Generator
 - DC Flywheels & ultra capacitors
- UPS – one element in high 9's system
 - System design for redundancy
 - UPS paralleling for redundancy and capacity
 - Static UPS bypass
 - Manual / Maintenance bypass



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Today's UPS Market Drivers

- Power quality under utility disturbances
- Flexible architectures for high 9's reliability
 - Parallel redundancy
 - Expandable for capacity
- High system reliability, MTBF
 - No single point failure

Interruption Costs	
Business / Industry	Cost
Paper Industry	\$10,000 – \$30,000 / event
Textile Industry	\$10,000 – \$40,000 / event
Data Processing	\$10,000 – \$40,000 / event
Plastics Industry	\$10,000 – \$50,000 / event
Semiconductor Industry	\$10,000 – \$50,000 / event
Automotive Manufacturing	\$15,000 / event
Air Traffic Control	\$15,000 / minute
Office Building	\$2,000 per 100 kVA of critical load
Broadcast Facility	\$100,000 / 30 minutes

Source: EPRI - Power Quality Applications Guide for Architects and Engineers

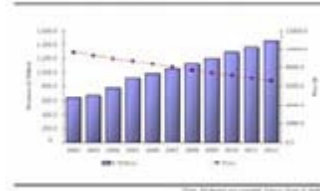
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Today's UPS Market Drivers

- Low installation cost
- Low operating cost - high efficiency
- High power quality utility interface
- High power density
- Serviceability – MTTR
- Multi - power source compatibility
- Global sourcing and manufacturing
- Monitoring, diagnostics & prognostics
- Maintenance services

U.S. & World's UPS Market Being From 2000 to 2012



- Revenue → ~10% growth / yr
- Price → ~ 4% \$ reduction / yr

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Today's UPS Technology

- Market drivers are addressed by:
 - Design for reliability
 - Scalable multi-unit operation for high 9's architectures
 - Elimination of single point failures
 - Fault identification and selective trip
 - Power module topology and design
 - Converter modulation and control techniques
 - Modular power and control modules
 - Build a scalable product line via modularity



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Converter Design for Reliability

- HALT: Highly Acceleration Life Test
 - Thermal cycling, rapid thermal transitions, load cycling ...
 - Identify weakest link via product destruction

- HASS: Highly Accelerated Stress Screen
 - Ongoing production screening.
 - Verify production units continue meet reliability objectives

- MTBF targets
 - UPS Converter > 60,000 hrs
 - Parallel redundant systems > 300,000hrs



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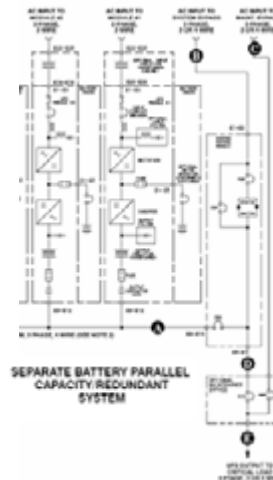
System Level Modularity and Scalability

System Level Drivers:

- Key to achieving high 9's of reliability
 - parallel for redundancy
- Parallel for capacity - load expansion

Enablers

- Eliminate single point failure
 - power & controls
- Communication less paralleling
Hot Sync™ Technology
- Fault location detection



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Power Availability for Mission Critical Apps

The power grid typically provides 3 - 9's, or 99.9% reliability. This equates to almost 9 hours of downtime per year. 'High 9's' are generally considered to mean 6 - 9's and above.

<u>9's</u>		<u>Downtime per Year</u>
3	99.9%	8 hr, 45 min, 36 sec
4	99.99%	52 min, 33.6 sec
5	99.999%	5 min, 15.36 sec
6	99.9999%	31.5 sec
7	99.99999%	3.15 sec



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Increasing Availability of Power

Parallel redundant systems offer substantially increased availability

- Can provide "high 9's" availability
 - The best opportunity to increase availability at the source
- There are two fundamental technical issues to solve for parallel redundant power systems
 - Control and stability of two or more AC power sources being paralleled
 - Elimination of all potential system-level single-point-of-failure
- The resulting performance is depending on design implementation of:
 - Load sharing
 - Fault isolation

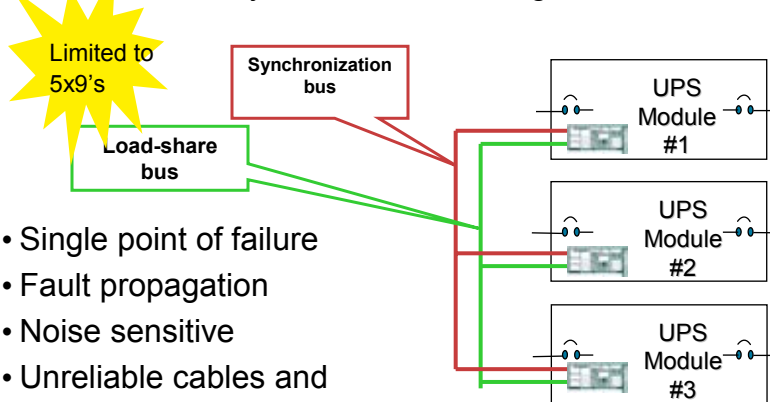
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Legacy Systems

Load share and synchronization wiring between modules



- Single point of failure
- Fault propagation
- Noise sensitive
- Unreliable cables and connections

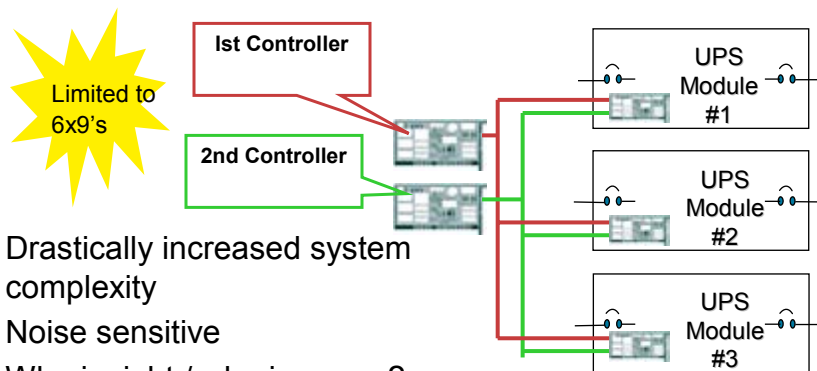
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Legacy Systems

Master / redundant controllers



- Drastically increased system complexity
- Noise sensitive
- Who is right / who is wrong?
- Unreliable cables and connections

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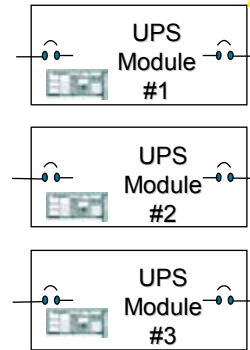
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Powerware Hot Sync™

“Wireless” paralleling of AC sources

- Reduced system complexity
- No single point of failure
- Modules are identical
- Modules act as peers
- No Primary / Secondary relationship
- No “Main Intelligence Module” required



Can provide
7x9's

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Powerware Hot Sync™

Hot Sync™ provides automatic load sharing and selective tripping in a parallel system.

- No control wiring required between modules for current sharing or selective tripping
- Designed to share load with any power source, including the utility
- Provides flexibility and scalability
- The UPS can be decentralized into the server equipment and still operate in parallel with additional server racks
- Ideal for distributed power system applications

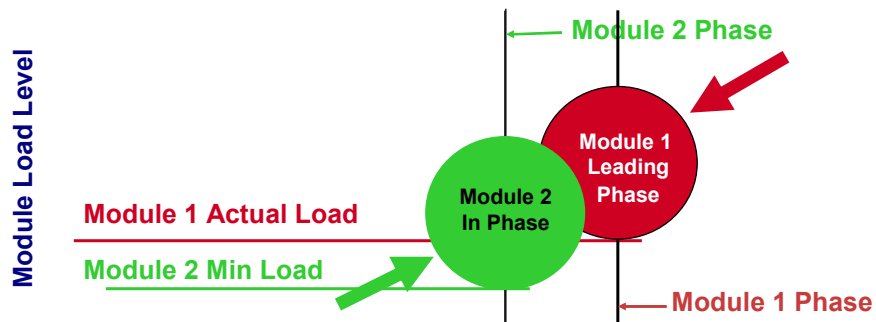
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Hot Sync™ Load Share Pictorial

Parallel load share control algorithm constantly drives the module to carry the least amount of load. This will drive Module 1 back in Phase with Module 2.



•Eaton developed technology – US patents #5,745,356 & 5,745,355

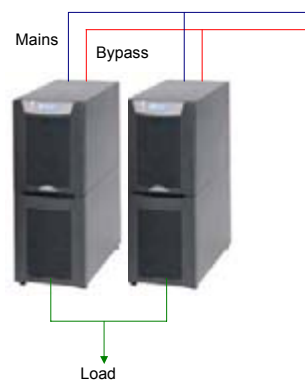


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Hot Sync™ Benefits

- Can provide up to 7x9's availability of power
- Ultimate scalability with no additional controls
- Modules in Parallel:
 - are absolute peers
 - have absolute autonomy
 - use 100% intrinsic components
- Seamless transition from capacity to redundancy
- Increased serviceability



Direct extension to autonomous operation of grid interface
Scalable DG converters

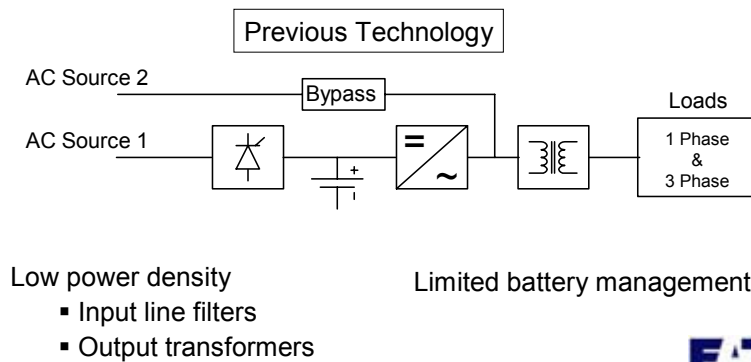


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Input Power Quality and Efficiency

- Online UPS: maximum protection from utility disturbances
- Source 3-wire and 4-wire loads.
- Maintain efficiency > 95%
- Manage battery lifetime



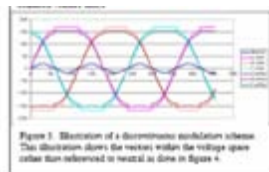
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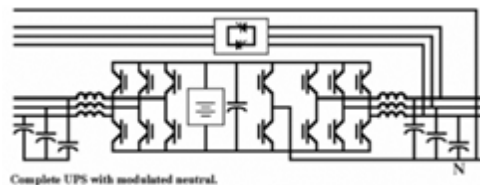
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Input Power Quality & Efficiency

- Active front end IGBT Converters (10-200kVA) improve:
 - Power quality, grid and generator interface
- Transformerless Double-Conversion UPS Topology
 - Elimination of distribution transformers (4 wire source / loads)
 - Novel modulation scheme for 4 leg inverters
 - Maximized DC bus utilization to maintain efficiency
 - Ultra small filter size: optimization of magnetic component & switching frequency



Increased power density



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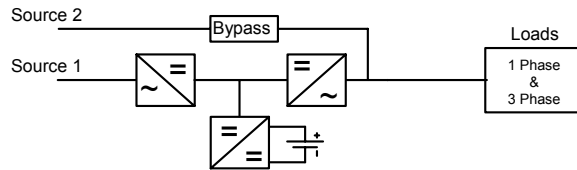
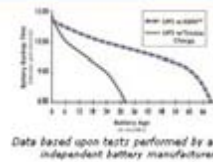
Battery Management

- Battery Systems

- Advanced Battery Management:

- 3 stage charging technique - doubles battery life & optimizes battery recharge time.
 - Prognostics / Diagnostics- provides up to 60-day advanced notification of the end of useful battery life.

- ProActive Service – max uptime via 24x7 corrective maintenance, remote monitoring



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Modular Product Approaches

- Motivation

- Build a product line to cover wide power range
 - Maintain low cost and high reliability
 - Enable N+1 redundancy: high MTBF
 - Serviceability - Maintain low MTTR

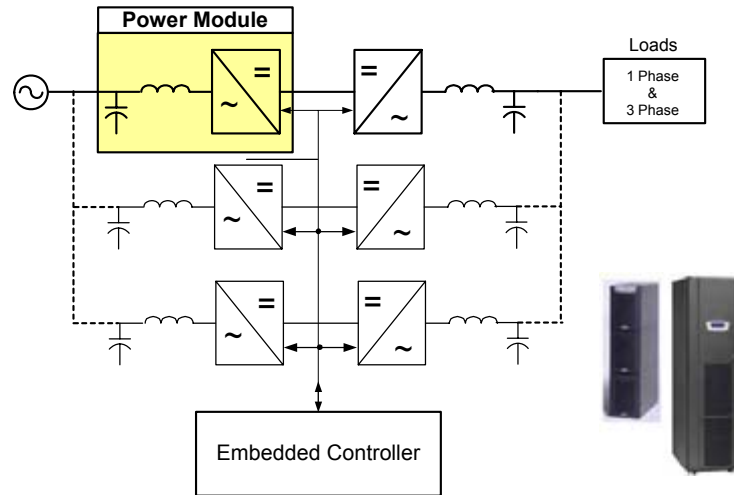
- Where is the appropriate division and extent of modularity ?

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Modular Power Block Approach



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Rack Mount Modular UPS

- **BladeUPS:**

- 12-60 kW modular, rack-based N+1 power protection



- **Features:**

- Very compact design, high power density (6U)..
- Highest power density on the market
- No single points of failure in system
- Mounts in any industry standard rack
- Each module is autonomous - establishes peer-to-peer relationship when paralleled.
- Hot Sync reliability, redundancy, and scalability
 - Scalable from 12kW to 60kW
- High Efficiency up to 97%
- Features hot-swappable battery modules and electronics
- Advanced Battery Management (ABM)



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Thank You

