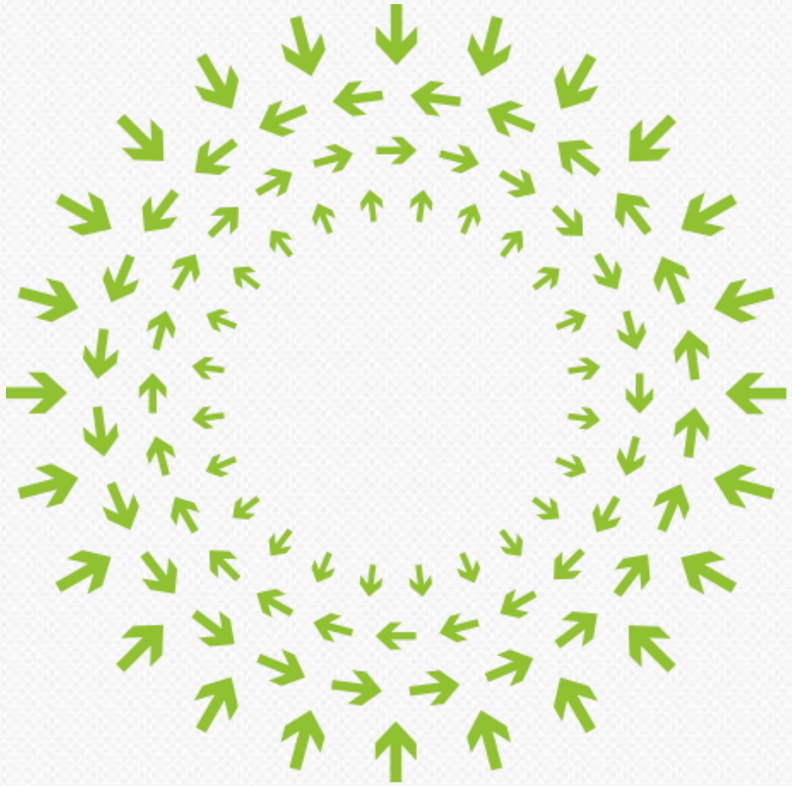

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Compute Engineering Workshop

March 9, 2015

San Jose

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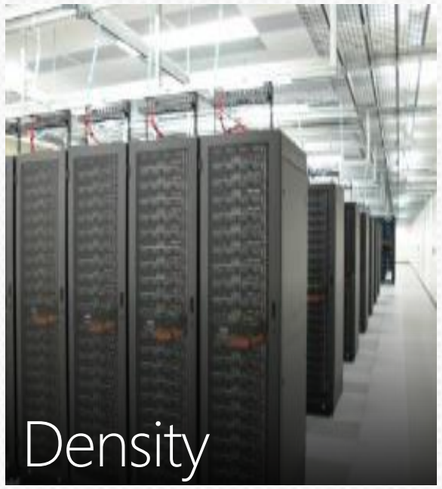
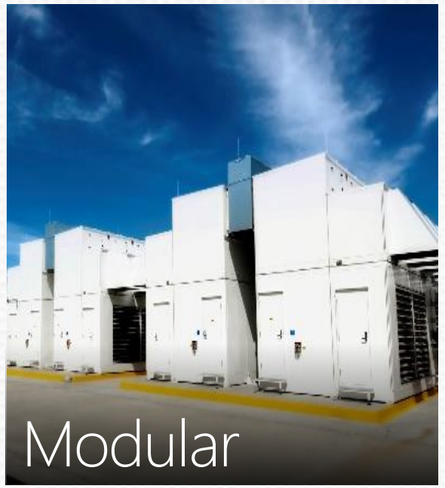
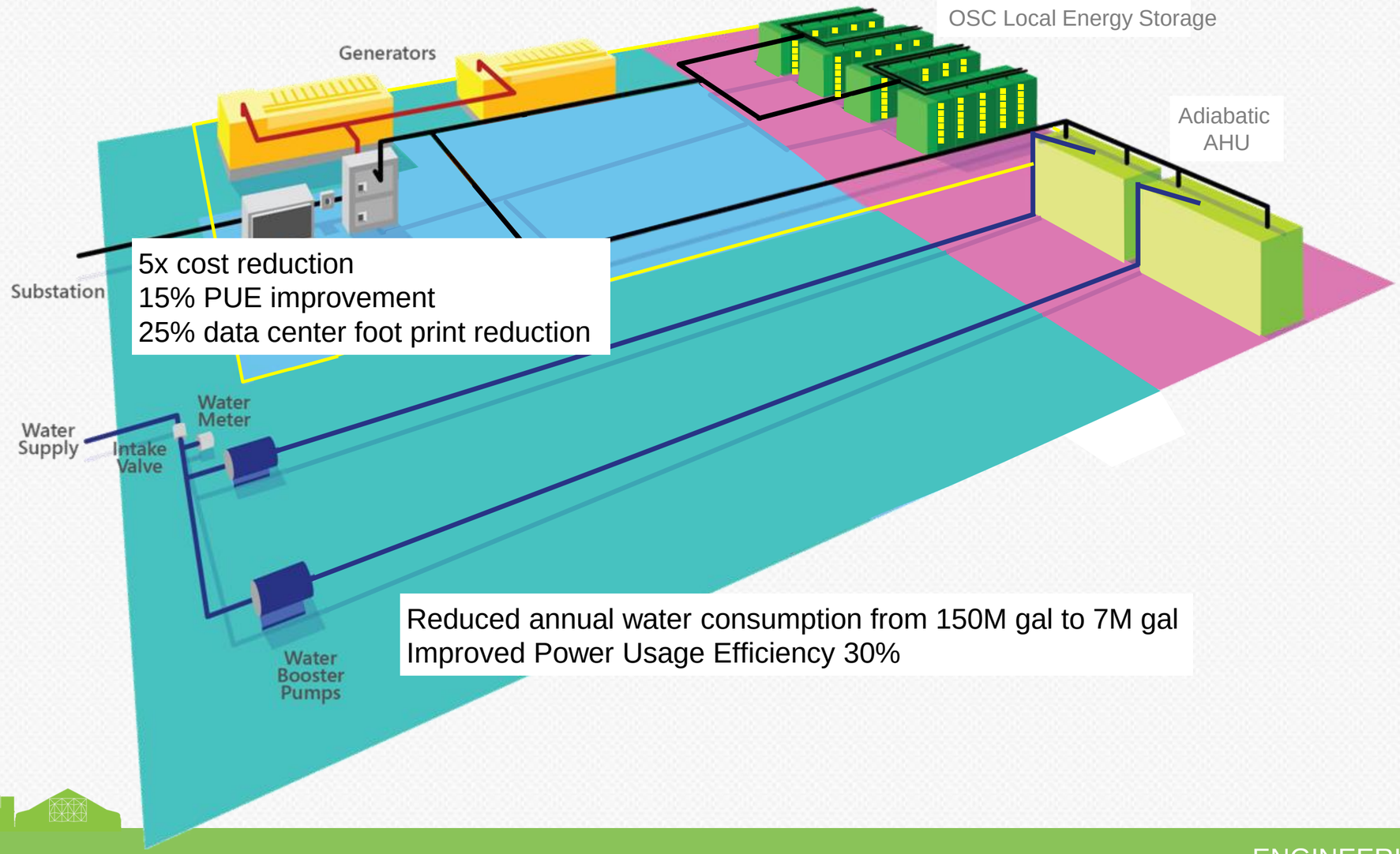
Microsoft OCS Distributed Local Battery Energy Power System

Shaun L. Harris
Director of Hardware Engineering
Windows Cloud Server Engineering

Microsoft's Hardware evolution

1989-2005	2007	2009	2012	2015
Generation 1 Data Center	Generation 2 Data Center	Generation 3 Data Center	Generation 4 Data Center	Generation 5 Data Center and Server
2.0+ PUE	1.4 – 1.6 PUE	1.2 – 1.5 PUE	1.12 – 1.20 PUE	1.07 – 1.19 PUE
 Colocation	 Density	 Containment	 Modular	 OCS Server Local Energy Storage
Server Capacity 20 year Technology	Rack Density & Deployment Minimized Resource Impact	Containers, PODs Scalability & Sustainability Air & Water Economization Differentiated SLAs	ITPACs & Colocations Reduced Carbon Right-Sized Faster Time-to-Market Outside Air Cooled	Reduced TCO Pay as You Go Capex Better Opex Predictable Performance Fail Small

Microsoft’s Hardware evolution



Options: Facility or Rack AC/AC UPS

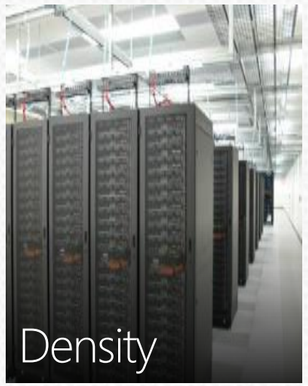
Facility

The *Institute* reduces the cost model to just two elements.

- The "kW" component by desired level of functionality:
  - Tier I: $10,000/kW of usable UPS output
  - Tier II: $11,000/kW of usable UPS output
  - Tier III: $20,000/kW of usable UPS output
  - Tier IV: $22,000/kW of usable UPS output
- The "computer room" component. In all cases, $220/ft² ($2,400/m²) of computer room floor must be added to the kW cost shown above.

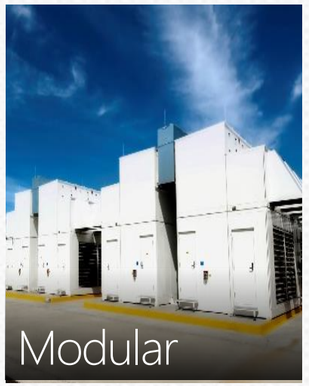
(source: The Uptime Institute)

Generation 2 Data Center

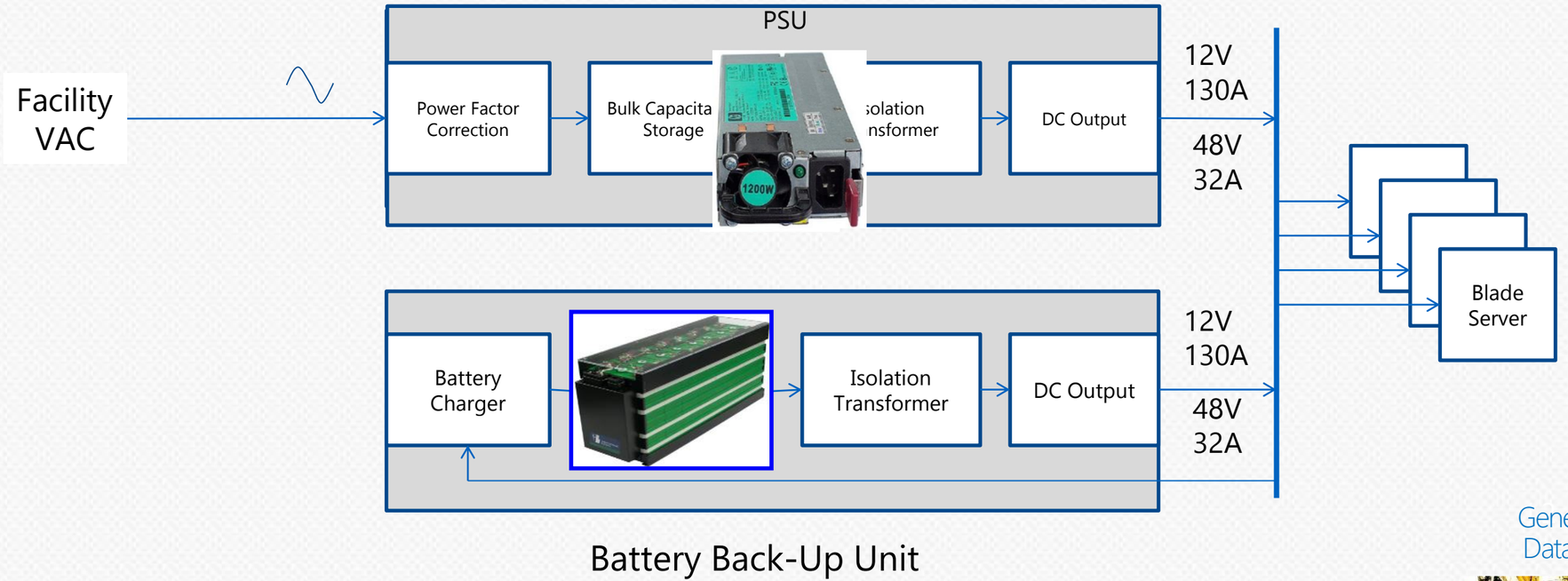


Generation 3 Data Center

Generation 4 Data Center



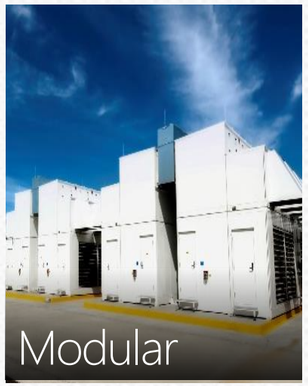
Options: AC/DC Common Bus BBU



Battery Back-Up Unit

Generation 3 Data Center

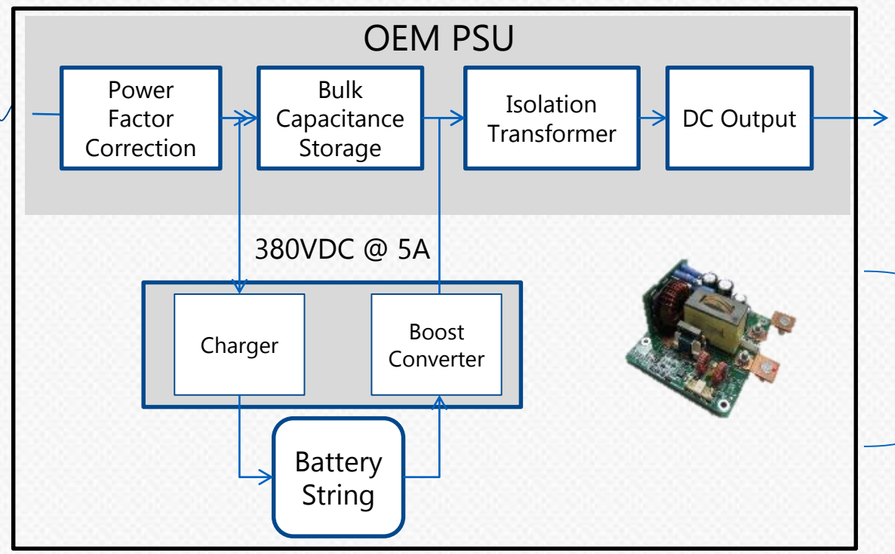
Generation 4 Data Center



OCS Local Energy Storage

Power Supply Unit (PSU) purchased with every server

Additional Parts

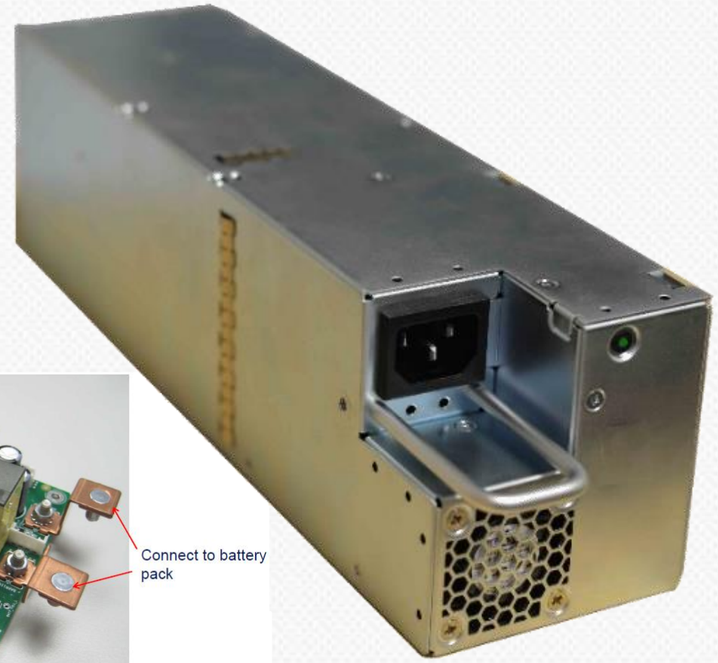


Low Cost Charge and discharge 380VDC low current

Lithium Ion Battery Pack Leveraged from Cordless Power Tool Market

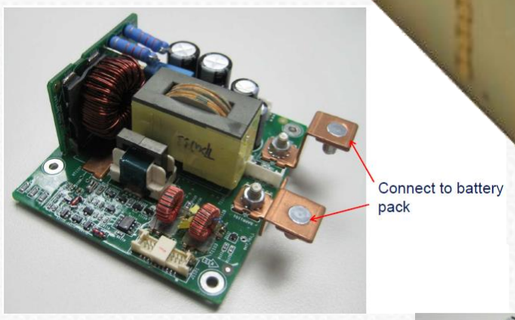
OCS Server Local Energy Storage

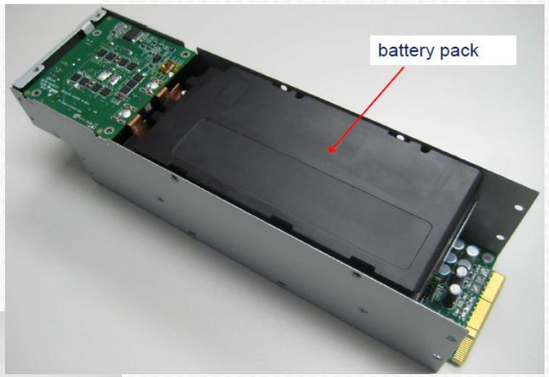
OCS Local Energy Storage



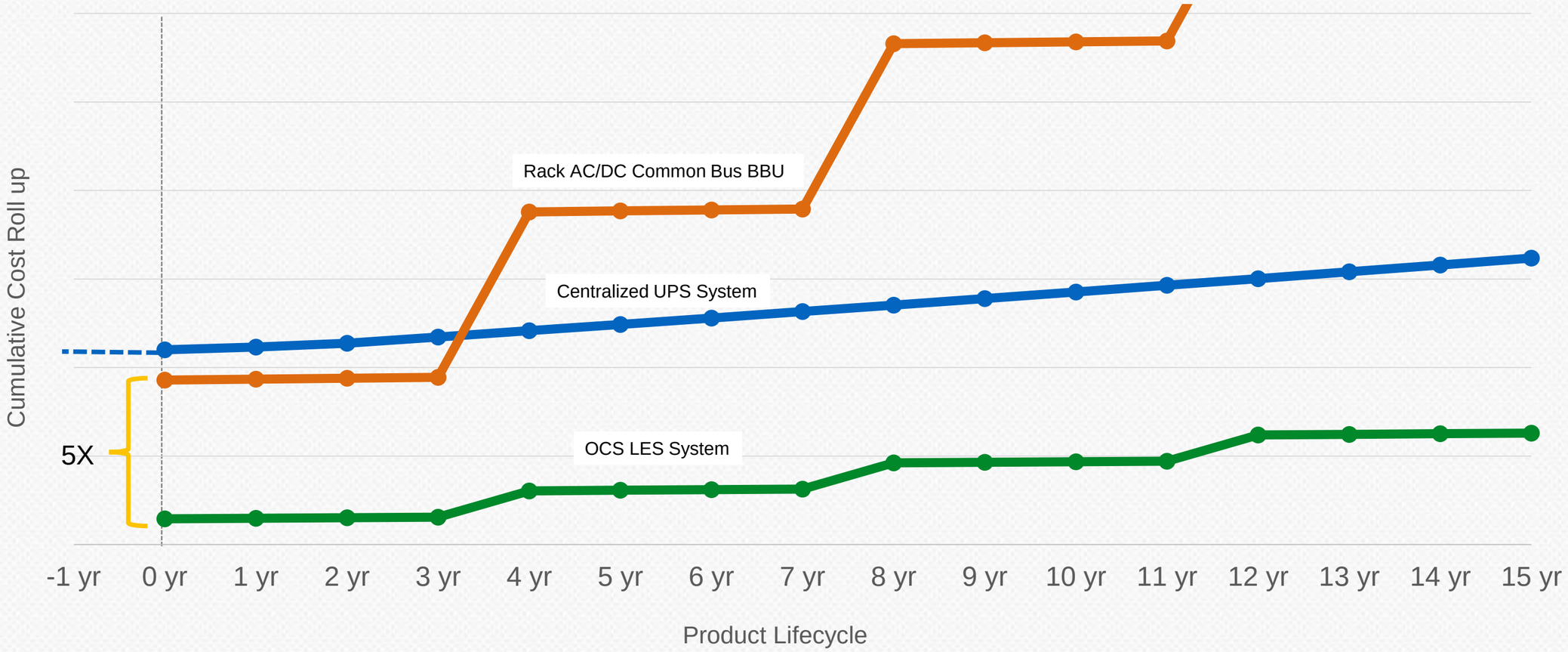
The key performance spec’s

- Ride thru 35 seconds + 10 second walk in at full load
- Up to 6 Year Life
- Wide operating temperature ranges, 50F to 95F
- Back to Back outages, 20 minute recharge period
- Battery Charge Overhead 2%
- Single phase loss transfer protection
- Built In battery, status, health and test, reported via the Chassis Manager
- Easy maintenance and repair, hot swappable design
- Predictable performance





Normalized Capex & Opex Cost Comparison



Distributed LES Advantages: Reduce Footprint

Eliminating Facility UPS systems and associated lead acid battery room reduces building by ~25%

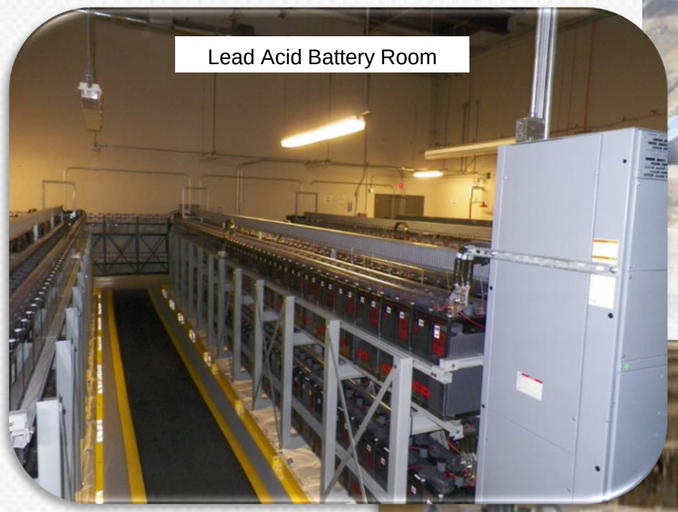
- Foundation & Basement works
- Superstructure
- Exterior skin
- Interior finishes
- Roof
- Site works
- Excavation
- HVAC
- Electrical

150k ft^2 reduction.
At \$220/ ft^2 = \$31M cost avoidance.

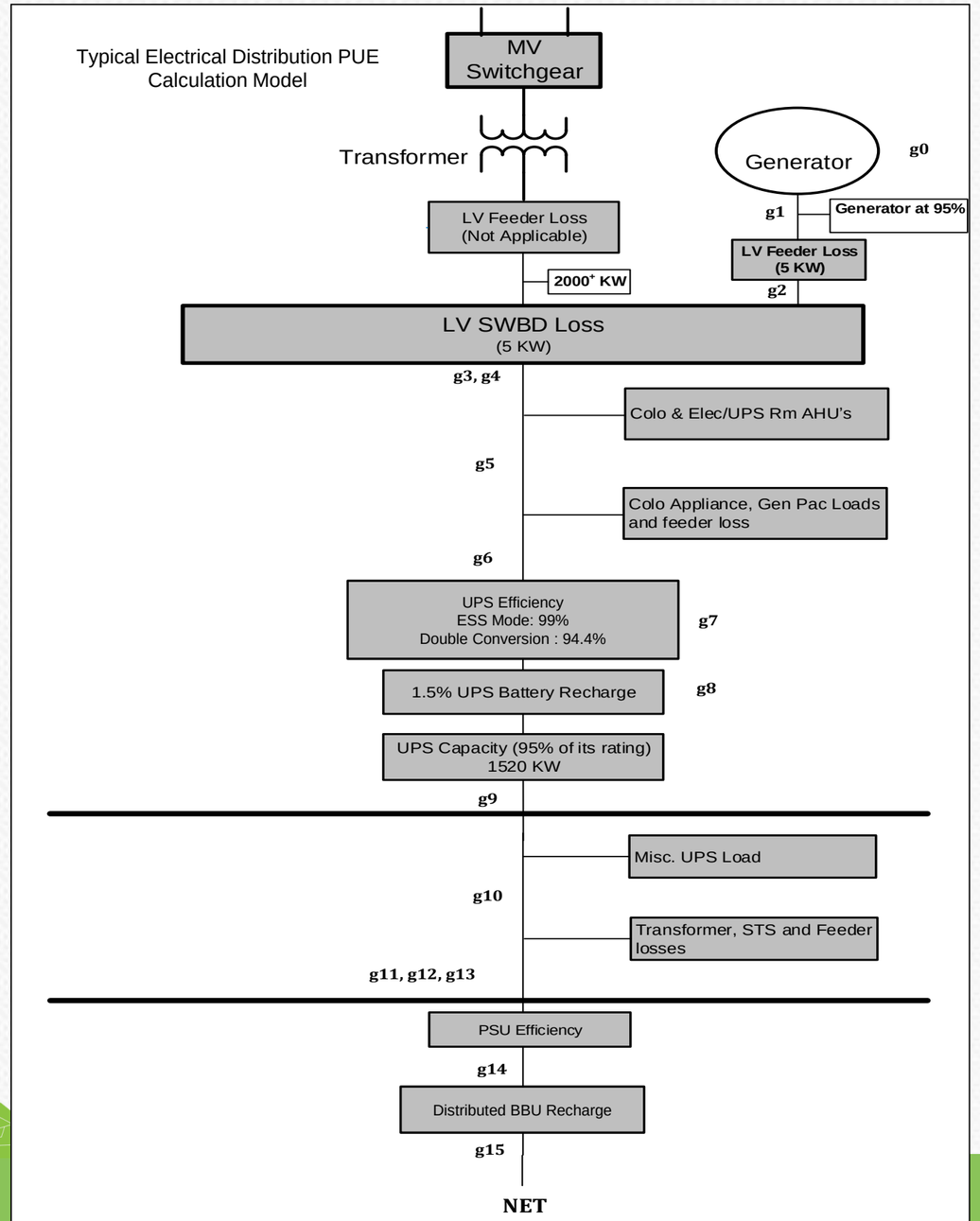
The *Institute* reduces the cost model to just two elements.

- The "kW" component by desired level of functionality:
  - Tier I: \$10,000/kW of usable UPS output
  - Tier II: \$11,000/kW of usable UPS output
  - Tier III: \$20,000/kW of usable UPS output
  - Tier IV: \$22,000/kW of usable UPS output
- The "computer room" component. In all cases, \$220/ft² (\$2,400/m²) of computer room floor must be added to the kW cost shown above.

(source: The Uptime Institute)



Distributed LES Advantages: Energy Efficiency

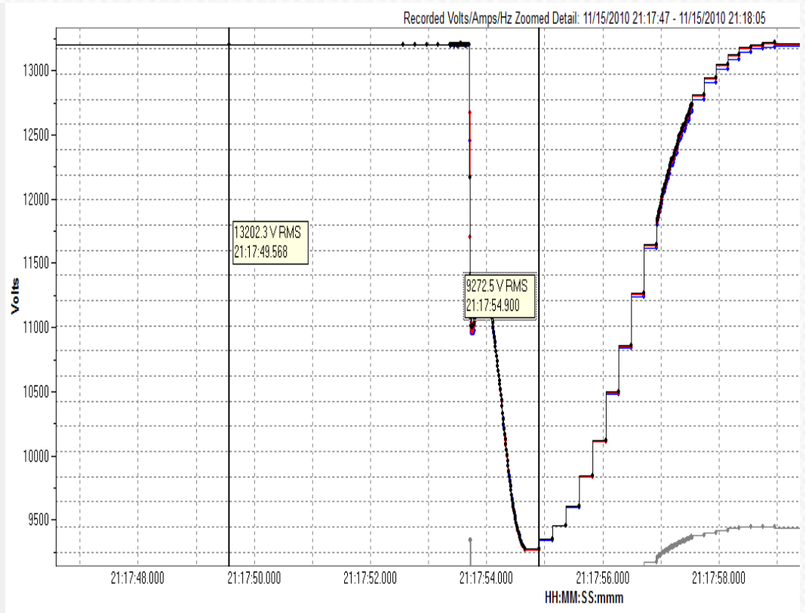


		Centralized UPS		OCS LES	
	Cell	Per Unit	1000kW	Per Unit	1000kW
g0	Generator	0.95		0.95	
g1	13.2KV, 2.5MVA Xfmr	0.00%	1000kW	0.00%	1000kW
g2	LV Feeder Loss	0.26%	997kW	0.26%	997kW
g3	LVSBD	0.20%	995kW	0.20%	995kW
g4	LVSBD-->UPS	0.07%	995kW	0.07%	995kW
g5	AHU Load	5.00%	945kW	5.00%	945kW
g6	Appliance/Ltg	1.00%	936kW	1.00%	936kW
g7	UPS Losses	8.00%	861kW	0.00%	936kW
g8	Battery Recharge	8.0%	792kW	0.0%	936kW
g9	UPS Capacity Reset	1.00%	784kW	0.01%	935kW
g10	Misc UPS Overhead	0	776kW	0.00%	935kW
g11	UPS STS Inefficiency	1.00%	768kW	1.00%	926kW
g12	UPS 480/415V Xfmr Loss	1.00%	761kW	1.00%	917kW
g13	UPS -Rack Feeder Loss	0.74%	755kW	0.74%	910kW
g14	PSU Inefficiency	6.00%	710kW	6.00%	855kW
g15	In System Recharge	0.00%	710kW	2.00%	838kW
g16	Critical Capacity @ Server PSU		710kW		838kW
			-129kW		
	Blade Qty @300W		2366		2794
	More Blades Per MW				**428**

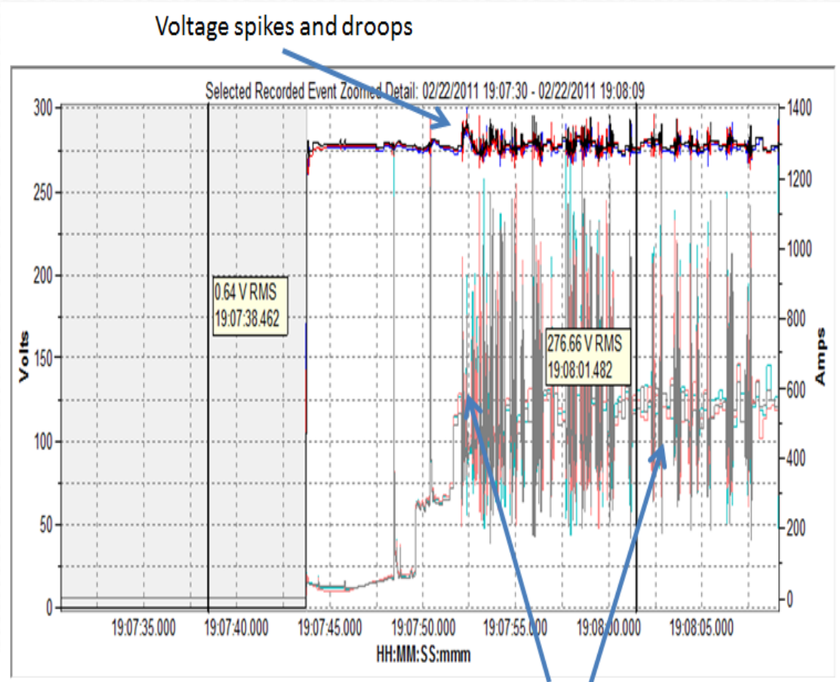
Advantage LES: Predictable Performance

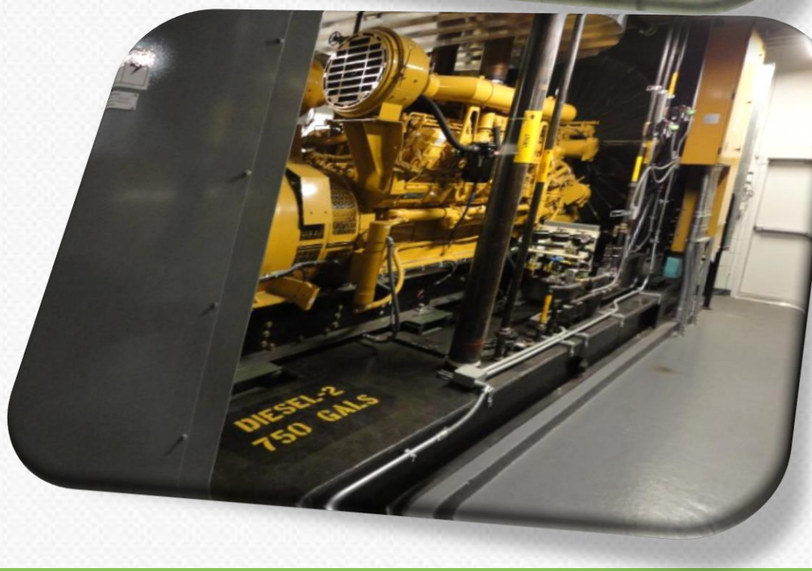
Diesel Generators have higher impedance and slower transient response than the utility. A large step function in current results in a droop in voltage which causes outages.

Data taken from commissioning with block load bring up sequence resulting in server power supplies turning on and off as a result of large step loads on the generator

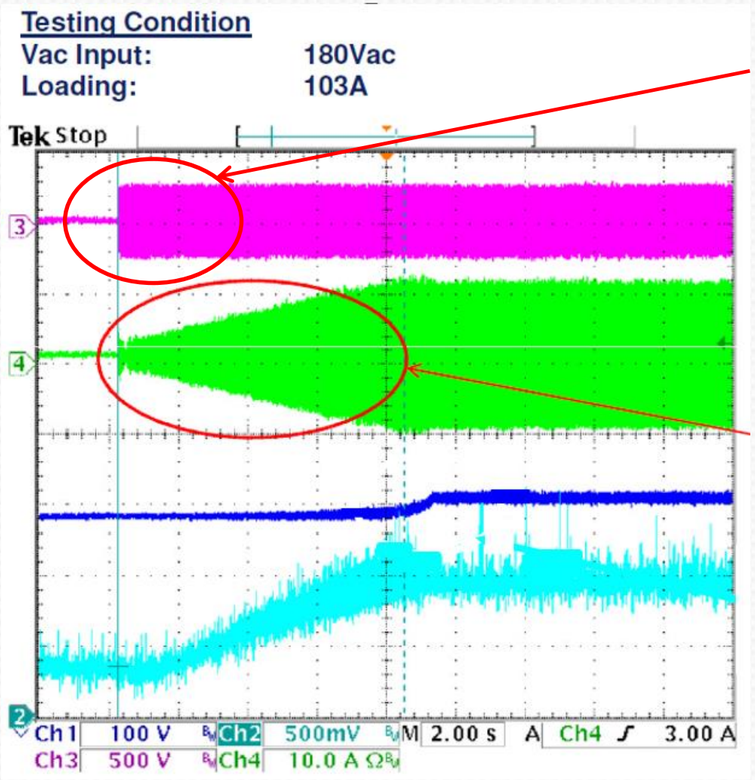


2.5MW 13.2KV Generator Set 100% step load (2.5MW) results in ***29.7%*** voltage droop.





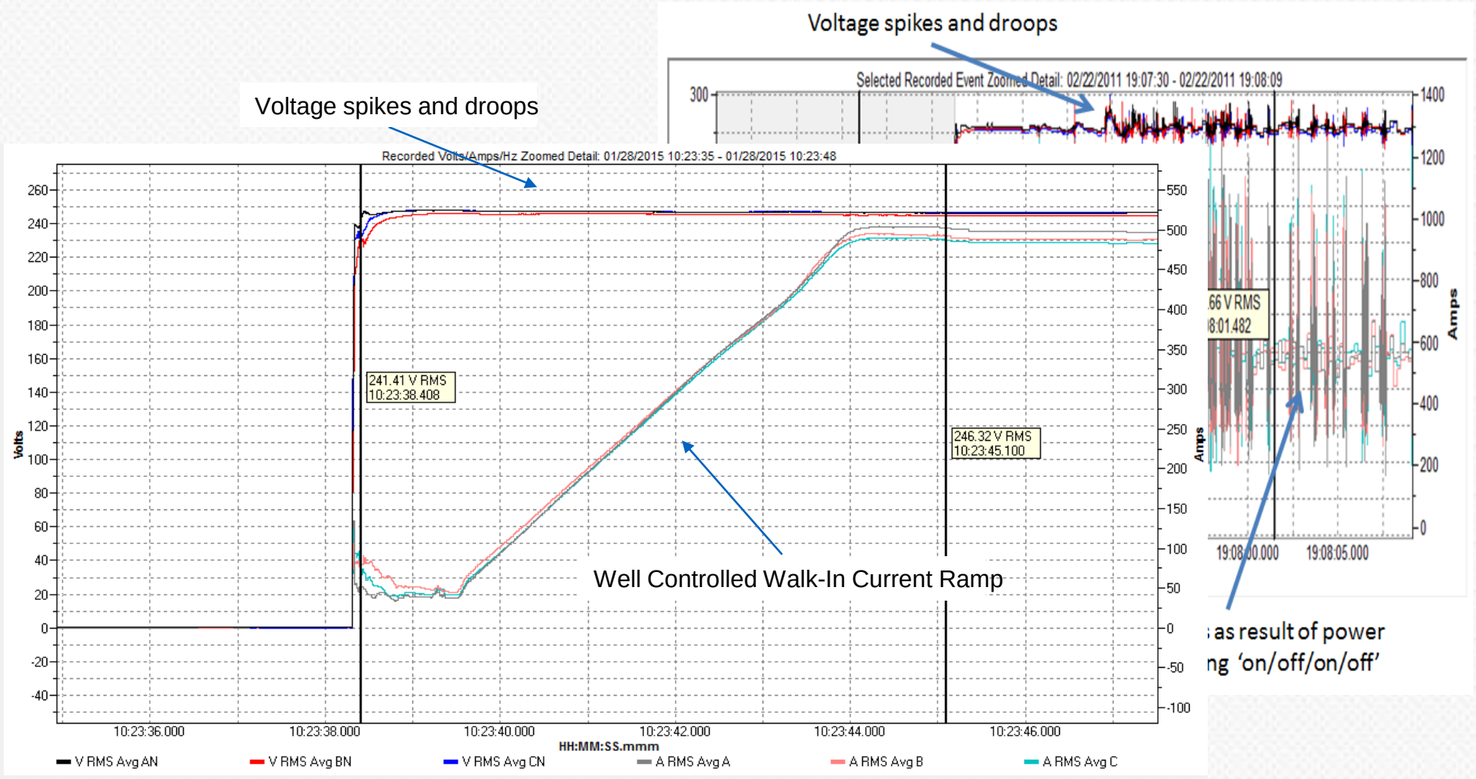
Advantage LES: Predictable Performance



VAC Outage and Return

AC Line current ramps at a predictable slope

Power Supply Line Cord Performance
1600W



Colo Level Electrical Distribution Performance
650kW

Advantages of a Local Energy Storage

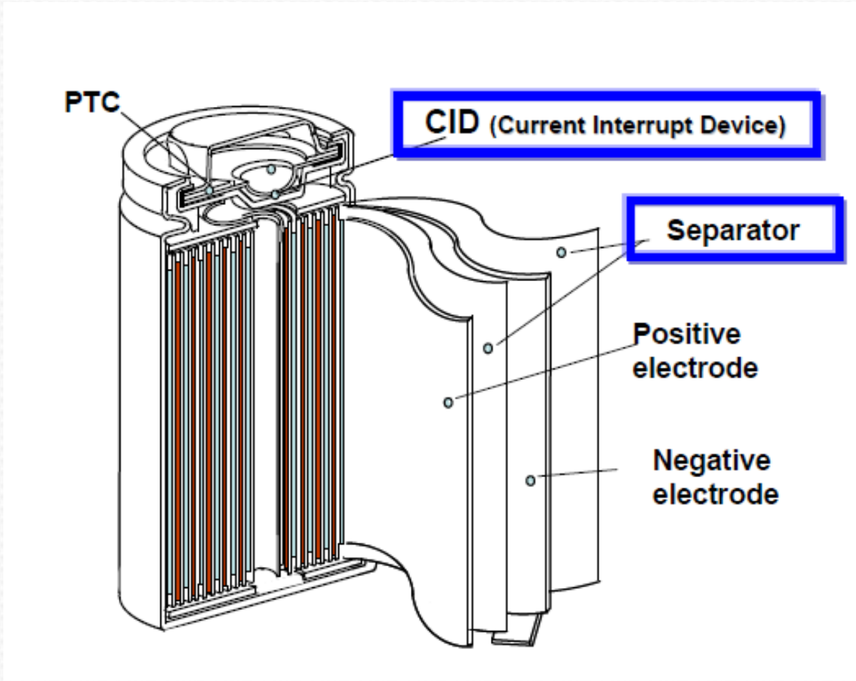
- Cost reduction
- Improved Power Usage Effectiveness.
- Reuse of existing circuits means fewer parts in the total system. Simplicity improves reliability
- Local Energy Storage in modular units enables a fail small model. Modular hot-swappable units improves MTTR. Improved IT availability.
- Pay-As-You-Go model.
- Unified UPS strategy. Predictable performance.
- Integrated, tightly coupled enables low latency controls.

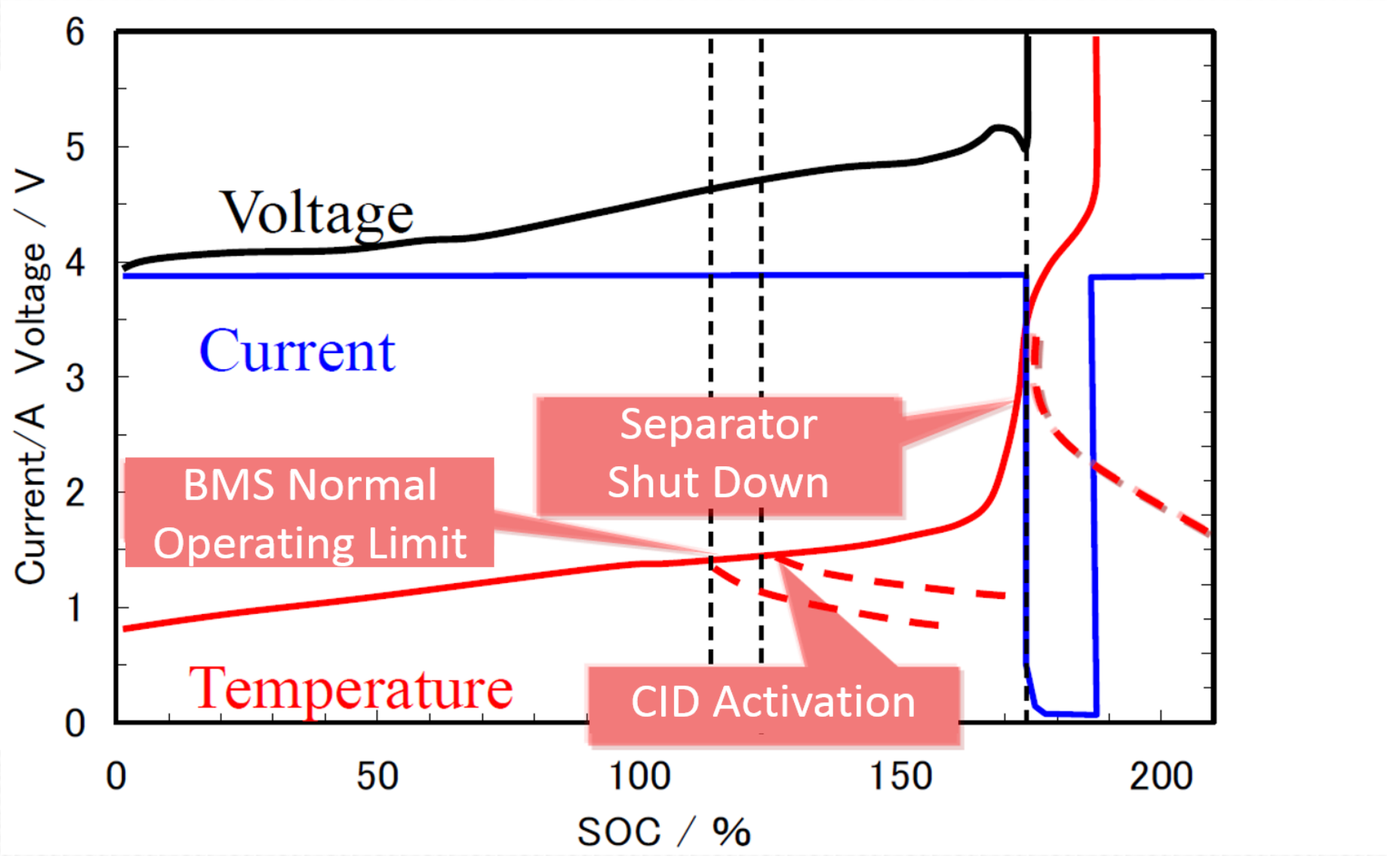
Commodity Battery Cell

Lithium Ion Battery x18650 Cell Safety UL and United Nations Test Requirements

Short Circuit
Abnormal Charging
Forced Discharge
Crush Test
Impact Test
Shock Test
Vibration Test
Heating Testing
Temperature Cycling
Low Pressure Test
Projectile Test

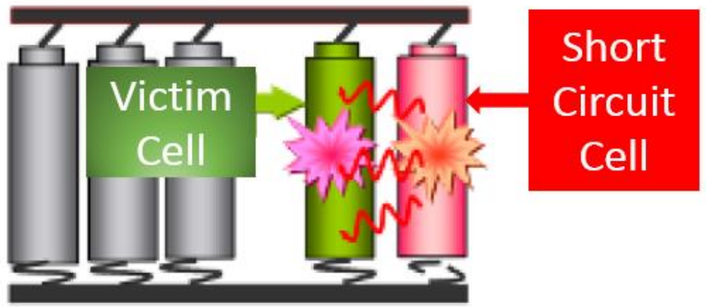
Lithium Ion Battery Cell Safety

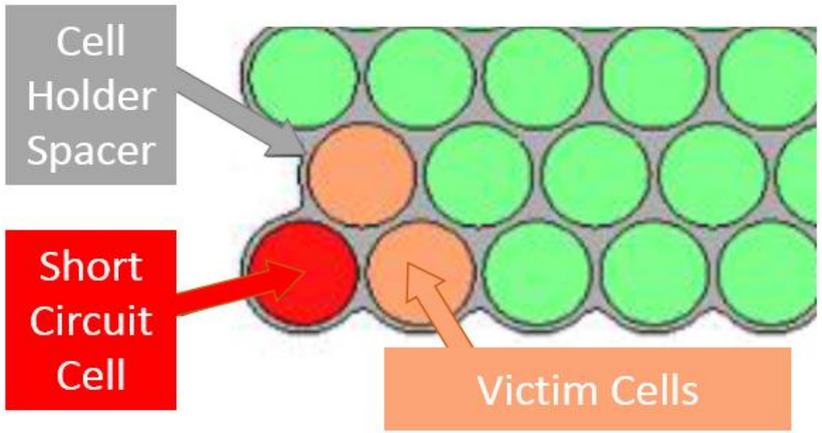




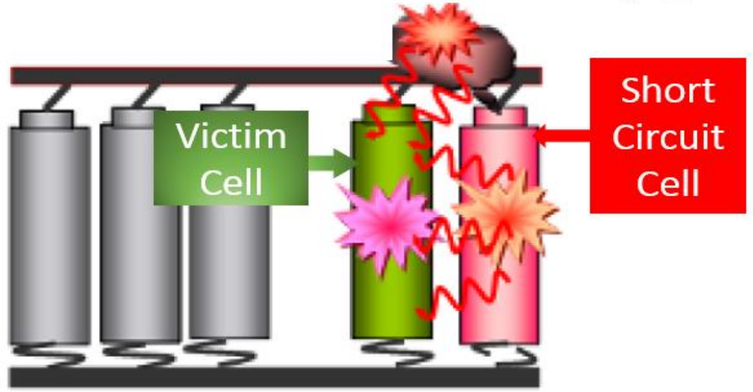
Lithium Ion Battery Pack Safety

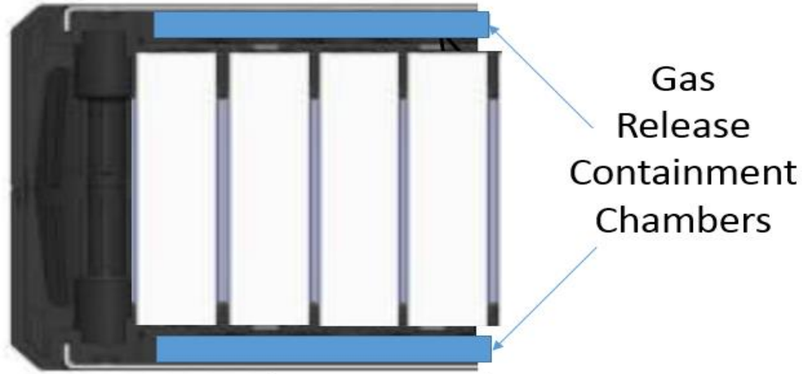
Cell thermal runaway and heat Propagation





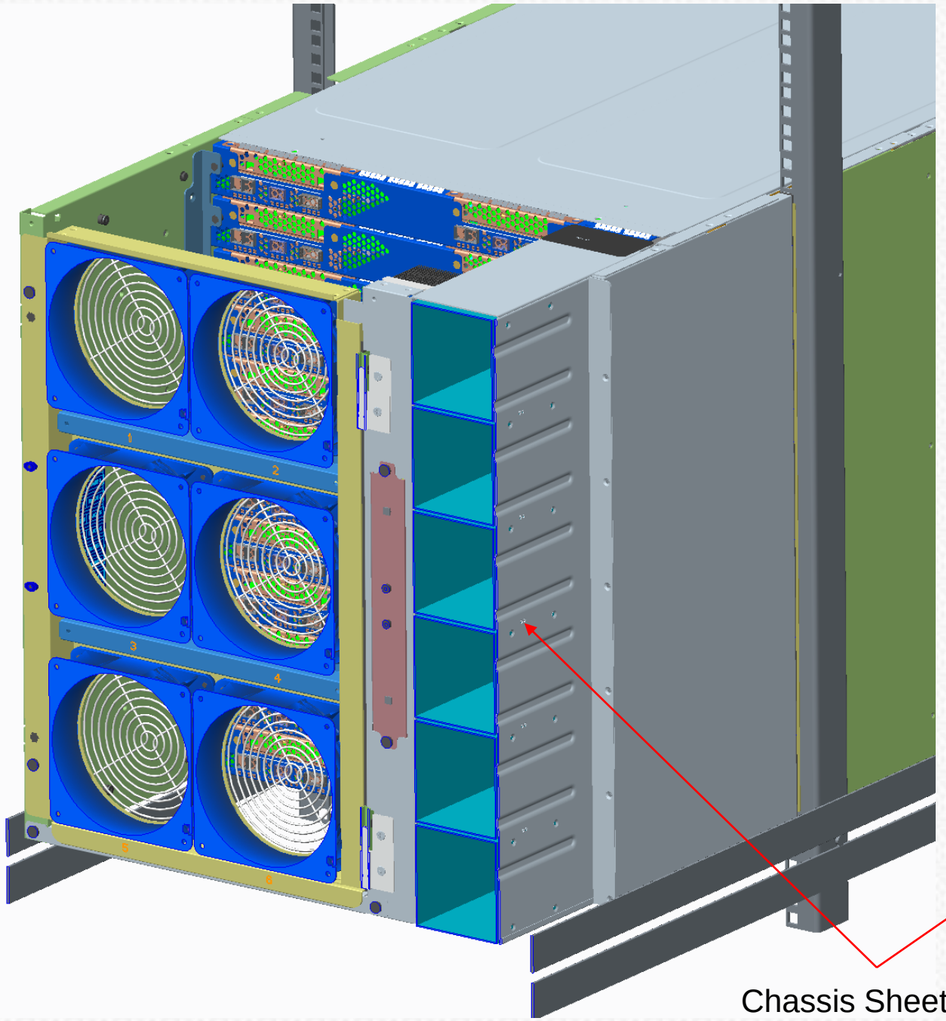
Cell Vent Combustible Gas and Propagation

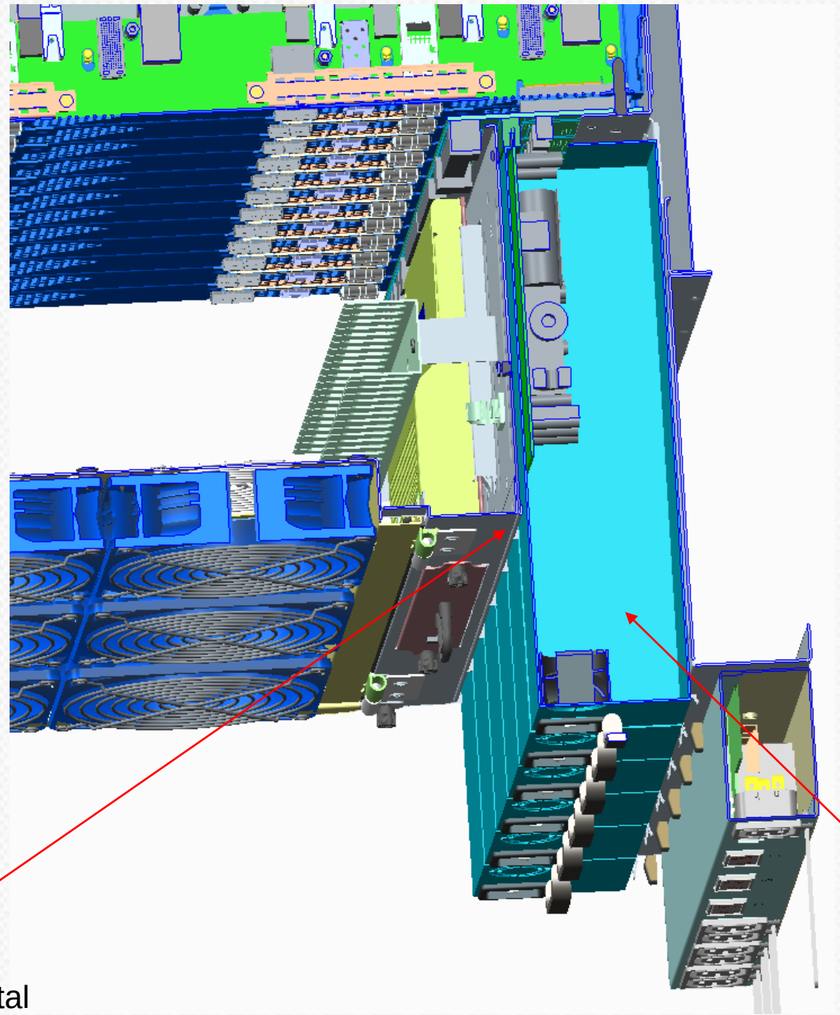




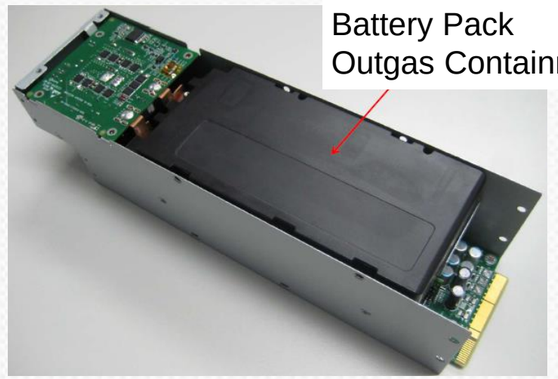
Cross Section of Battery Pack Case

Sheet Metal Containment





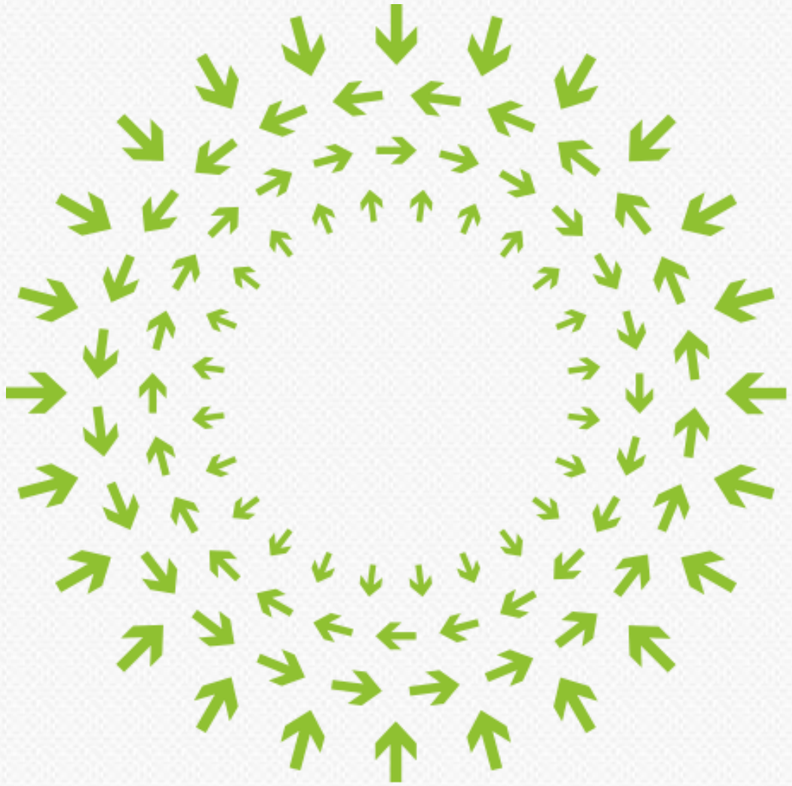
Chassis Sheetmetal Containment



Battery Pack Outgas Containment

PSU Sheetmetal Containment

Closing remarks



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