DC Distribution In Data Centers And Telecom Central Offices

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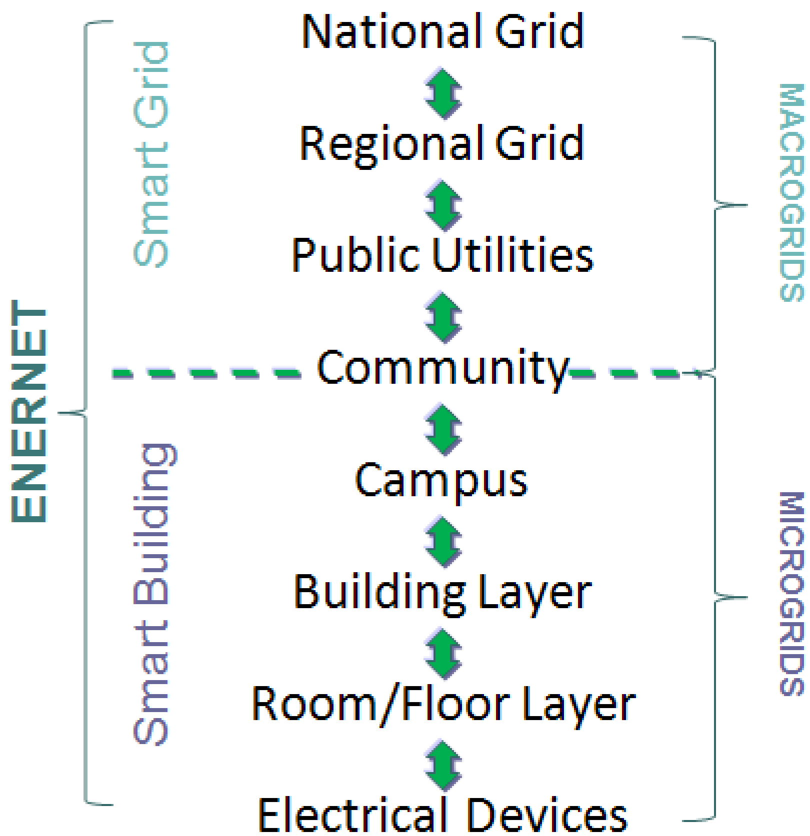
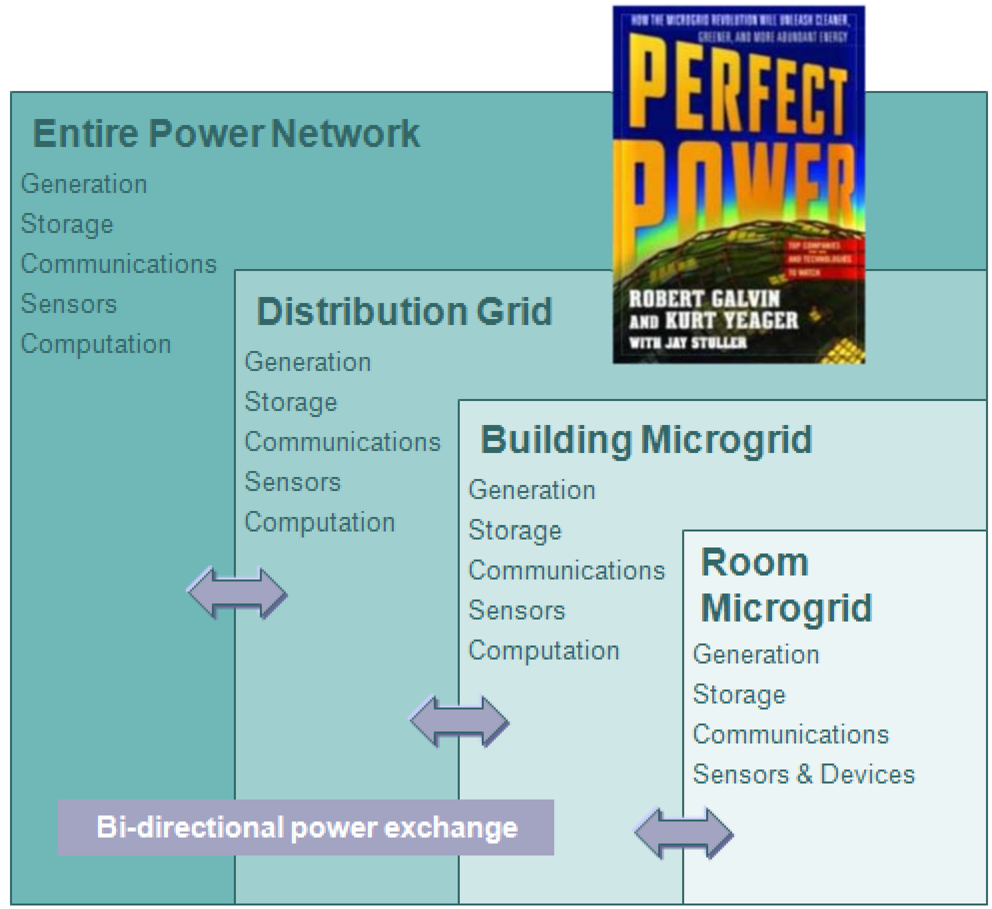
From Dept of Energy Secretary Steven Chu

- As Energy Secretary Steven Chu has noted, “America cannot build a 21st Century energy economy with a mid-20th Century electricity system.”
- Transforming the current grid into a dynamic, resilient, and adaptable Smart Grid will be one of the biggest technological challenges of our times. The rewards, however, may be dramatic, enabling consumers to better control their electricity use, integrating the next generation of plug-in electric vehicles, increasing efficiency, and better harnessing renewable energy.

Source: Department of Energy, Communications Requirement Of Smart Grid Technologies, October 5, 2010

Smart Grid to Smart Buildings:
Layered DC Microgrids at the Core of the New Energy Network





En•er•net: noun \en-ə(r)-net\ : the Internet of powered things Bob Metcalfe

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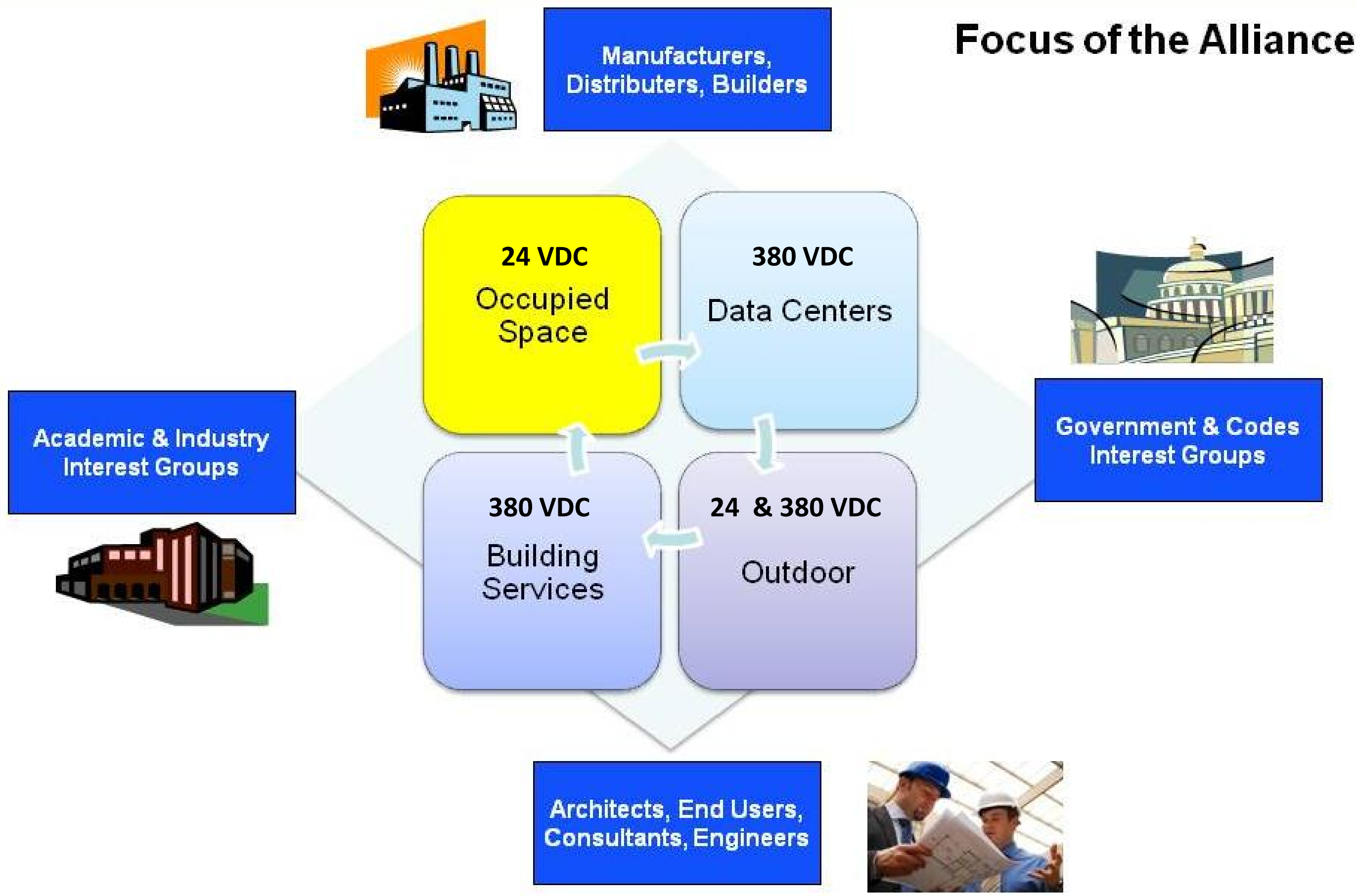
DC Microgrids Throughout Buildings



Source: EMerge Alliance Overview

Who Is EMerge?

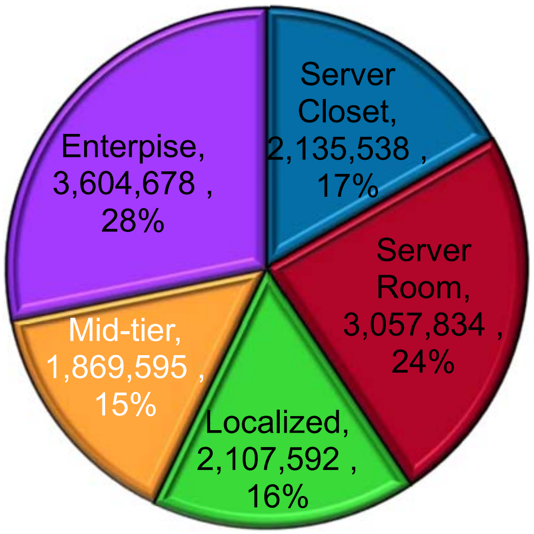
- Manufacturers
- Building Owners
- Technology Leaders
- Contractors/Builders
- Architects
- Engineers
- National Labs
- Codes & Standards Groups

Data Center Types, Sizes and Numbers

Type	Server Closet	Server Room	Localized Data Center	Mid-tier Data Center	Enterprise-Class Data Center
Scope	Secondary computer location, often outside of IT control, or may be a primary site for a small business	Secondary computer location, under IT control, or may be a primary site for a small business	Primary or secondary computer location, under IT control	Primary computing location, under IT control	Primary computing location, under IT control
Power/cooling	Standard room air-conditioning, no UPS	Upgraded room air conditioning, single UPS	Maintained at 17 C; some power and cooling redundancy	Maintained at 17 C; some power and cooling redundancy	Maintained at 17 C; at least N+1 power & cooling redundancy
Sq ft	<200sq ft	<500sq ft	<1,000sq ft	<5,000sq ft	>5,000 sq ft
US data centers (2009 est)	1,345,741 = 51.8%	1,170,399 = 45.1%	64,229 = 2.5%	9,758 = 0.4%	7,006 = 0.3%
Total Servers (2009 est)	2,135,538 = 17%	3,057,834 = 24%	2,107,592 = 16%	1,869,595 = 15%	3,604,678 = 28%
Average servers per location	2	3	32	192	515

Data Center Type and Server Population

Number of Servers by Data Center Type



0.7% of data centers (Enterprise & Mid-tier) contain 43% of all servers

(Amazon/Apple/Facebook/Google/Yahoo)

They have staffs of internal electrical & mechanical engineers to design & construct efficient data centers

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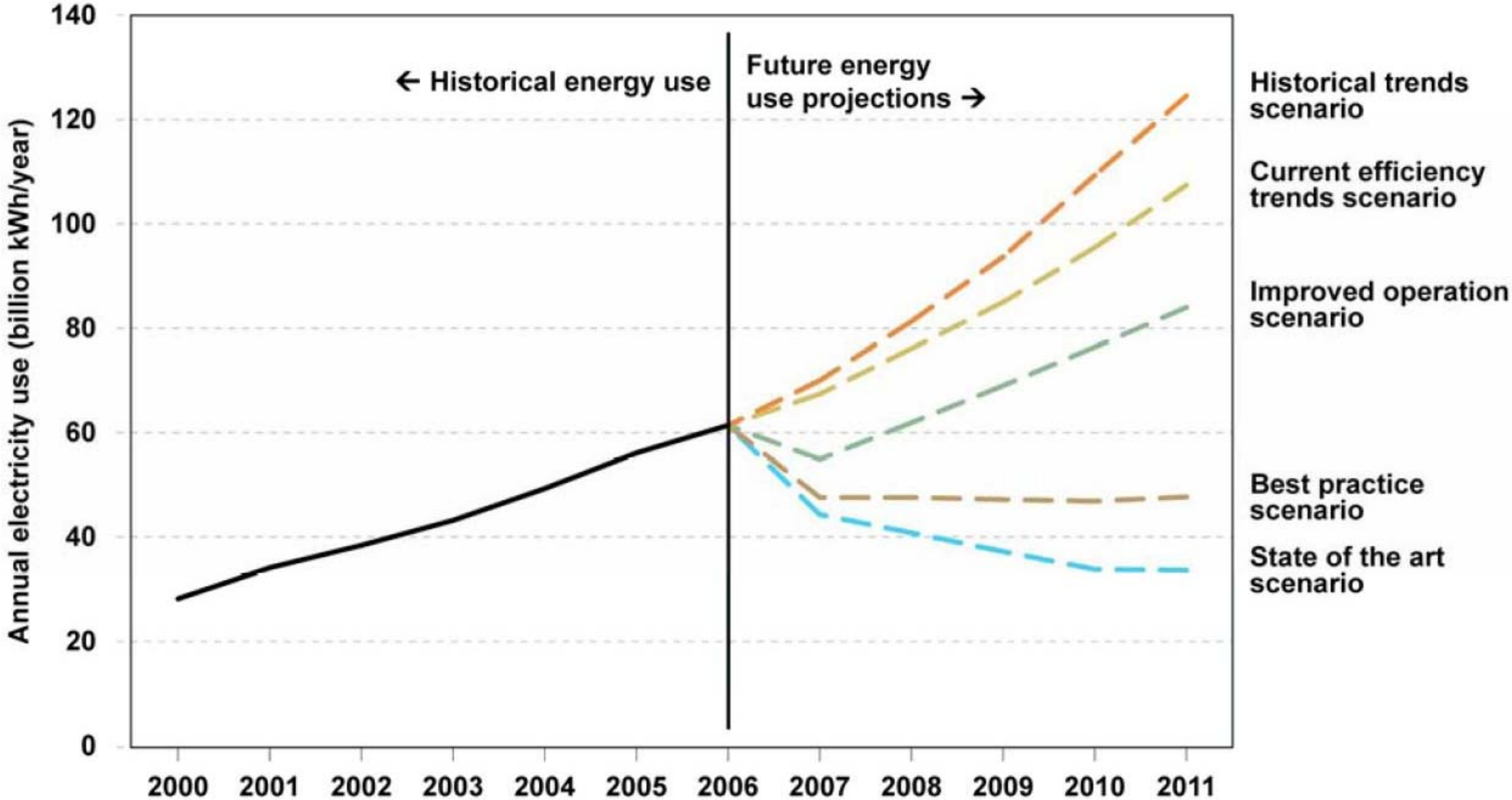
99.3% of data centers (more than 2.5 million of them) contain 57% of all servers

(Hospitals/Hotels/Universities/Utilities/Banks /City Halls/Supermarkets/Chain Stores)

These data centers operators struggle with heat/space/power problems without much internal expertise

Data Center Energy Use –Why It's Important! They used 1.5% of US Electrical Energy in 2006 & Growing To ~3% In 2011



From: EPA Report to Congress on Server and Data Center Efficiency, 2007. It is estimated that this sector consumed about 61 billion kilowatt-hours (kWh) in 2006 (1.5 percent of total U.S. electricity consumption) for a total electricity cost of about $4.5 billion

380VDC Data Centers?!? REALLY???

~28% facility energy savings, incl. cooling compared to “typical” AC system

~7% facility energy savings, incl. cooling compared to “best-in-class” AC system

~33% space savings

200% to 1000% reliability improvement

15% electrical facility capital cost savings

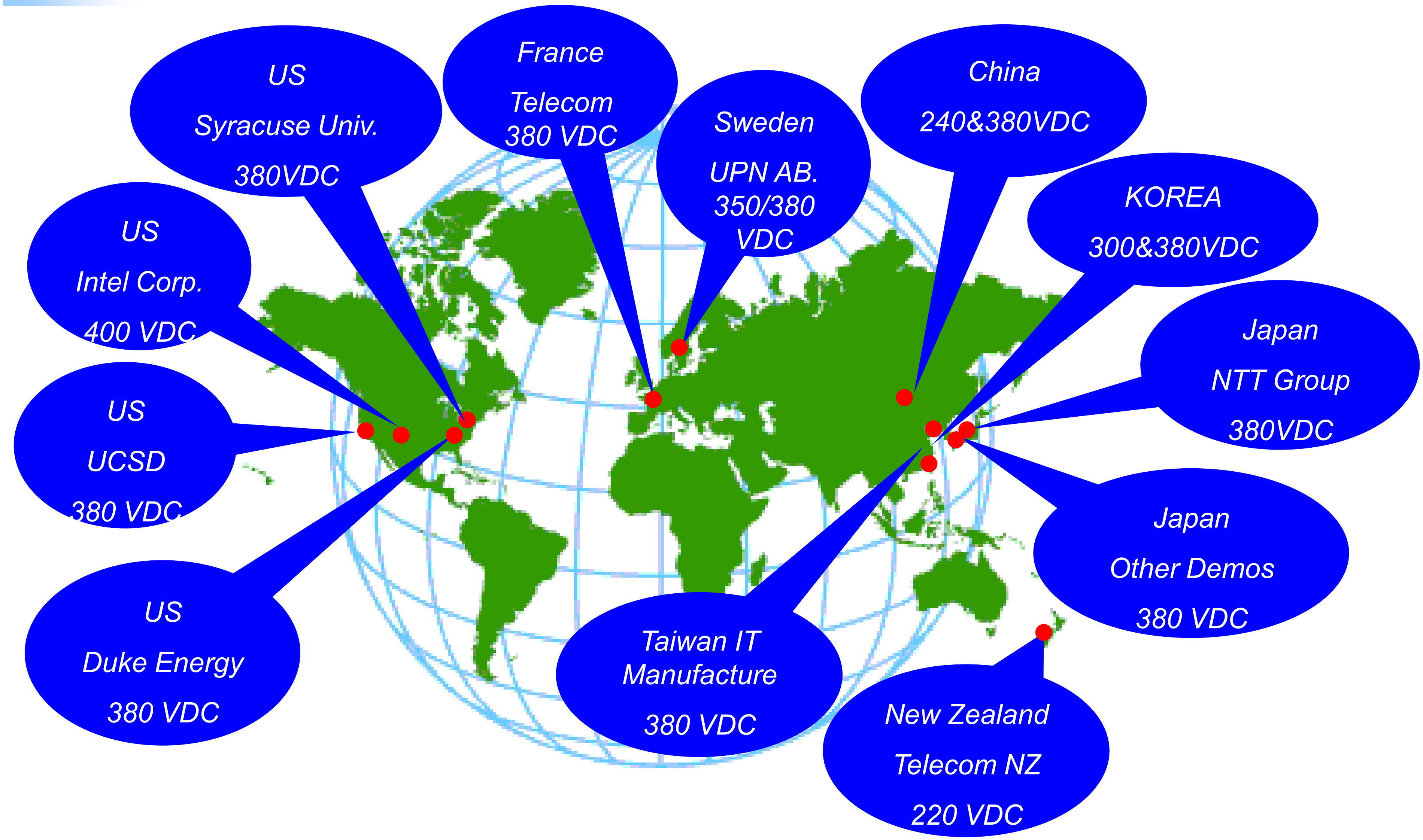
Overall heat load reduction reduces overall cooling requirement

Using fewer of the earth’s resources (15% component reduction)

380VDC Data Center Activity

- Involved With Multiple 380VDC Demos
  - Universities
  - Electric Utilities
  - Telecom Industry
- Harmonizing Multiple 380VDC Standards Efforts
  - DC Power Partners Joining EMerge Alliance
  - European Telecommunications Standards Institute
  - International Electrotechnical Commission (SG4)
  - NFPA 70:National Electrical Code (2011>>>2014)
- Working With Many Manufacturers
  - IT Equipment As Well As Facility Equipment

Worldwide ~380VDC Demos



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Telecom Central Offices Are Consuming More Than 1% Of Total Worldwide Electrical Energy

Country	Network	Energy Consumption	% of Country Total Energy Consumption
USA	**Verizon 2006**	**8.9 TWh**	**0.24%**
Japan	**NTT Group 2007**	**5.54 TWh**	**1%**
Italy	**Telecom Italia 2005**	**2 TWh**	**1%**
France	**France Telecom-Orange 2006**	**2 TWh**	**0.4%**
Spain	**Telefonica 2006**	**1.42 TWh**	**0.6%**

Global electricity consumption of telecom industry estimated at 1%:

164 billion kWh

More than the total electricity consumption of Iran, Turkey or Sweden

Enough to power 1.6 million homes

110.7 million tons of CO2 (equivalent to the annual emissions of 29 million cars !)

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Data Centers versus Telecom Central Offices

Similarities

Both installing lots of computer equipment
Both adding new services & capabilities
(Central Offices looking more & more like Data Centers)
Both are running out of power & cooling & space

Differences

Data Centers	Telecom Central Offices
200-240 VAC	48 VDC
Commercial Grade Equip	Telecom-certified Equip
New/Modern Sites	Old/Downtown Sites

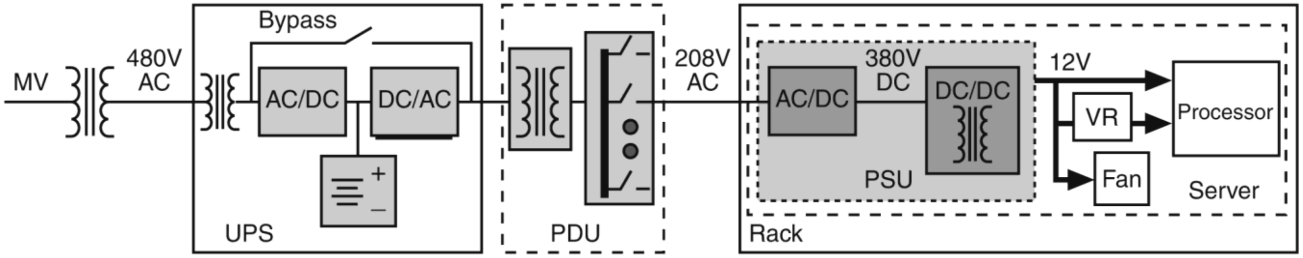
380VDC Data Center Demos

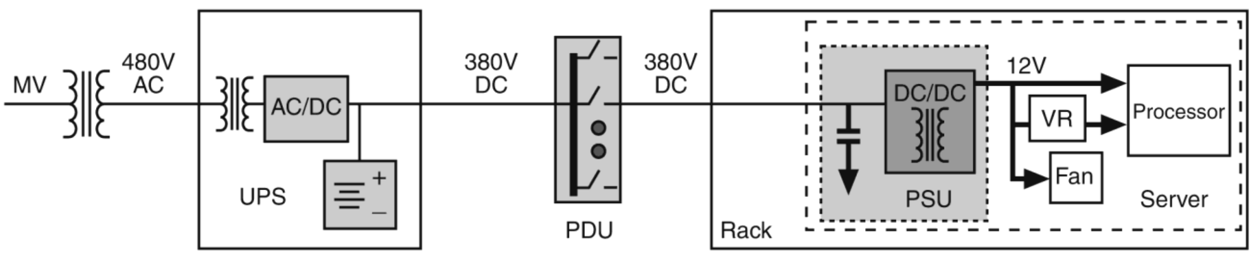
EPRI/LBNL - Electric Power Research Institute
Lawrence Berkeley National Lab, California

Duke Energy data center in Charlotte, North Carolina

Calit2 - California Institute for Telecommunications and Information Technology , UC San Diego

Standard 208VAC vs 380VDC Data Center





Duke Energy 380VDC Data Center Demo

HP Servers

IBM Servers

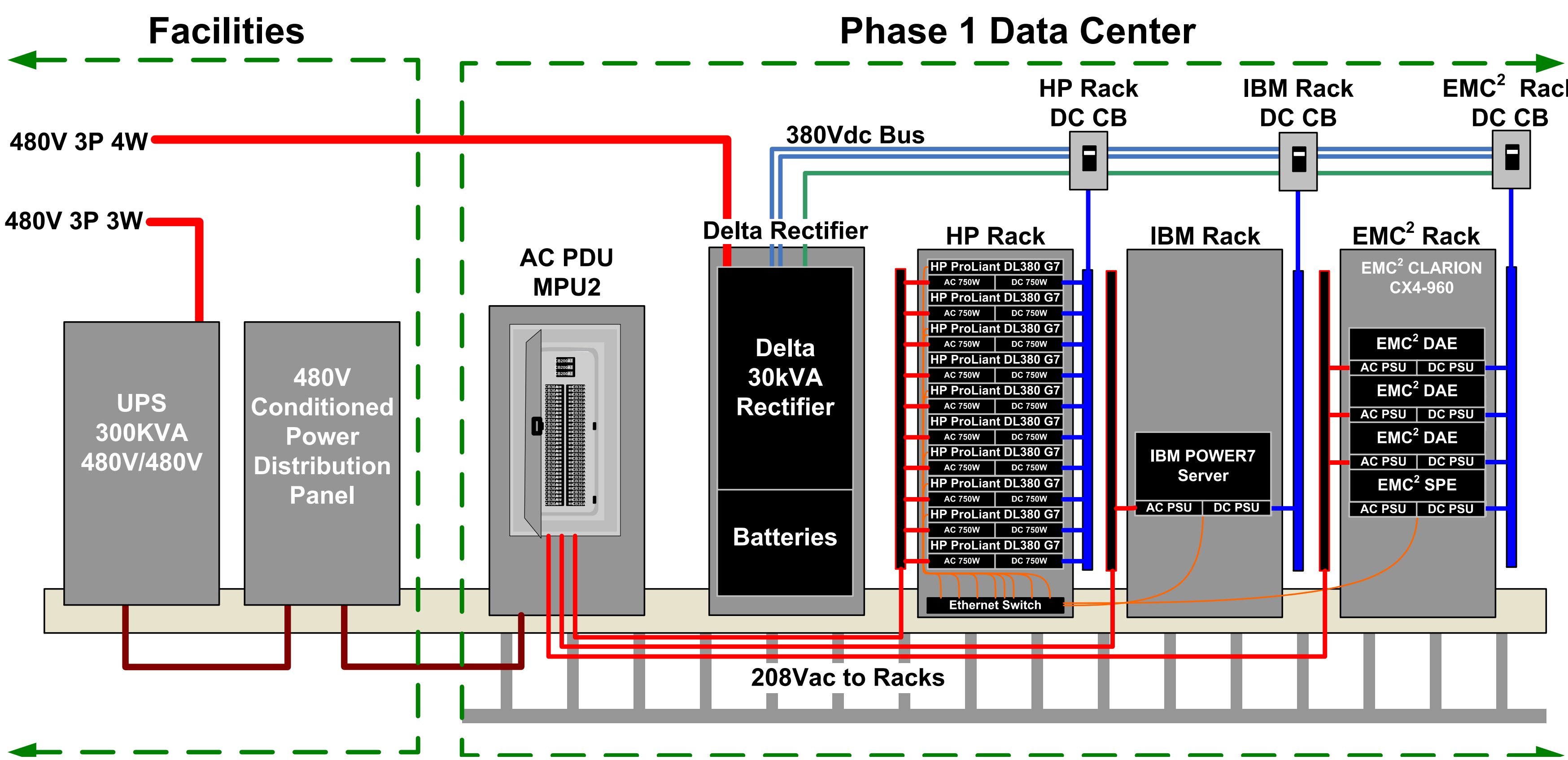
EMC Storage Arrays

Delta Rectifiers

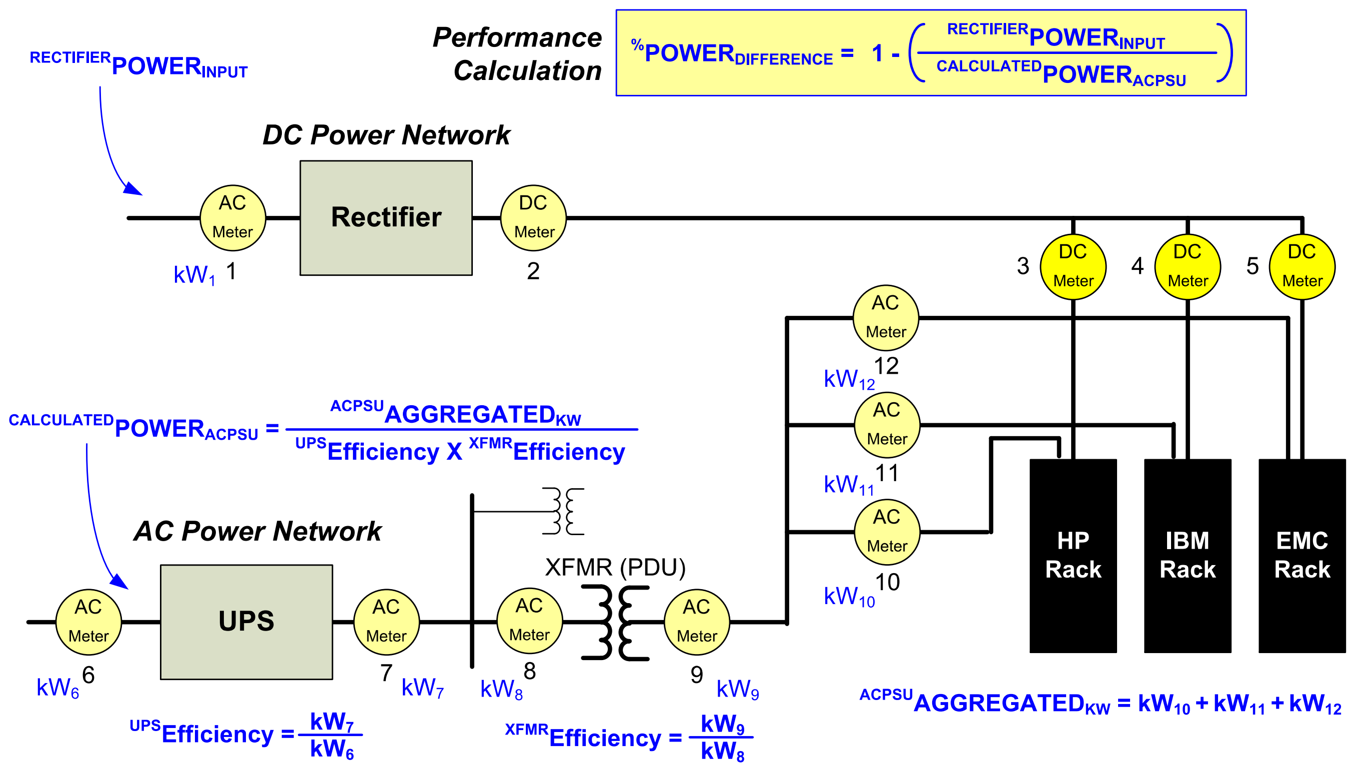
StarLine Busway

Dranetz-BMI Metering

Duke Energy Data Center Set-Up

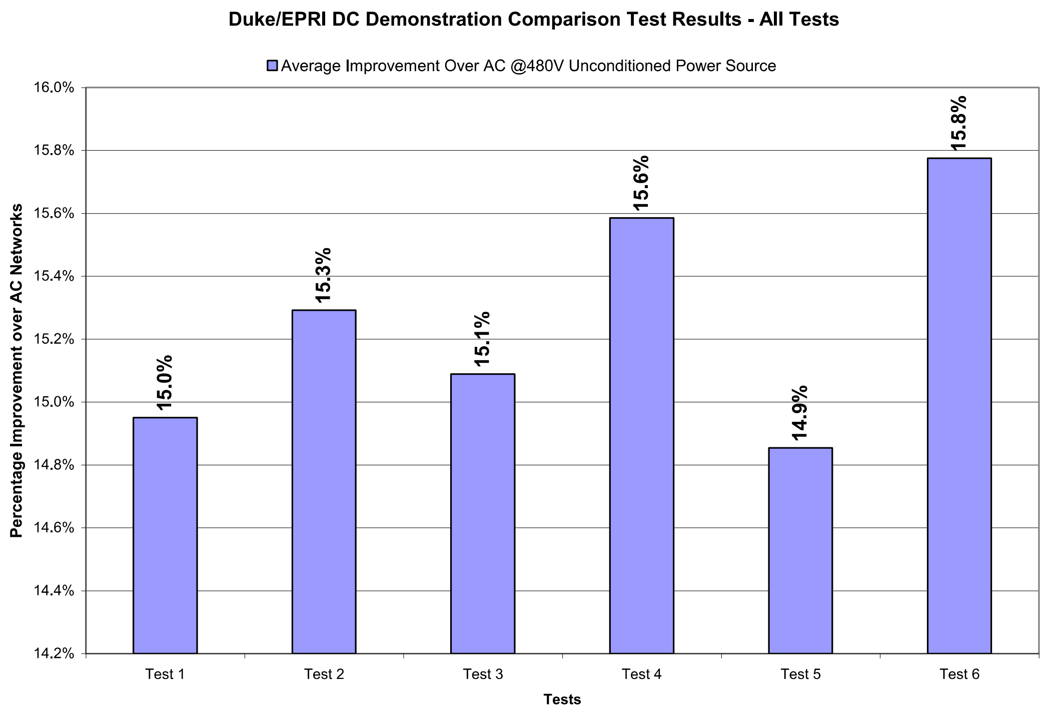


Duke Energy Data Center Metering Scheme



AC vs DC Comparison Tests

Test	Average Percent Difference Between AC and DC Network
Test 1	15.0%
Test 2	15.3%
Test 3	15.1%
Test 4	15.6%
Test 5	14.9%
Test 6	15.8%
Average	15.3%



- Test 1 – All servers and storage arrays "on" but "idle" (28 hours)
- Test 2 – IBM and EMC "on" but "idle" (28 hours)
- Test 3 – All servers and storage arrays running at 100% (8 hours)
    - IBM (nStress), HP (Prime95), EMC (IOMeter)
- Test 4 – All servers and storage arrays running at 50% (18 hours)
- Test 5 - All servers and storage arrays running at 100% (51 hours)
- Test 6 – IBM and EMC "on" but "idle" (19 hours)

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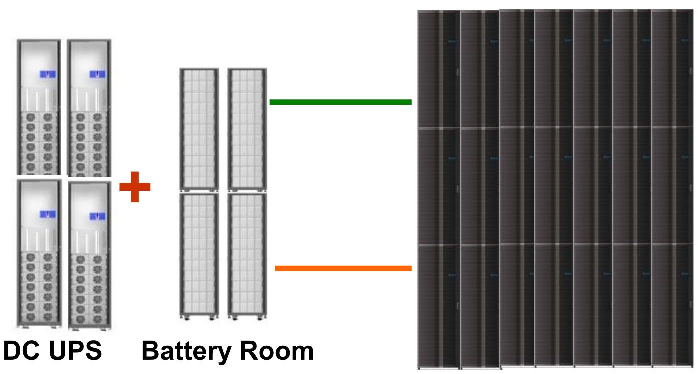
Delta Products - DC UPS

80kW 120kW 160kW ··· 280kW

- Modular design
- Hot-swappable control module
- 20kW per power module
- Redundancy Configuration

Facility Configuration



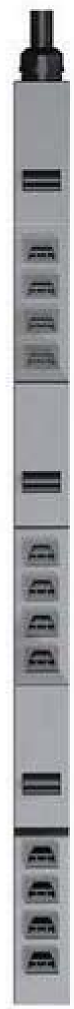
Row Configuration

Delta Products - Rectifier Module Spec

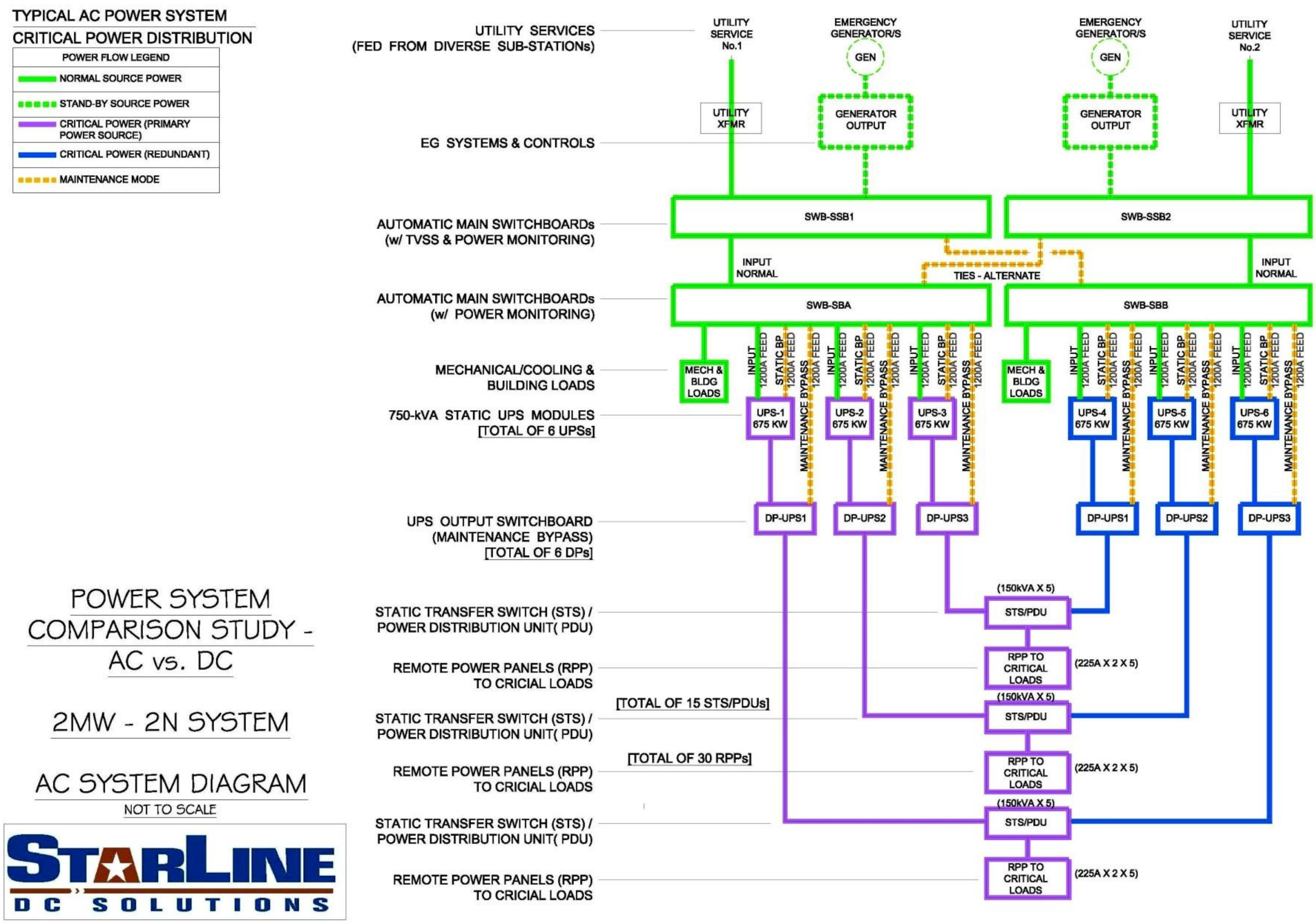
- Power Module capacity 20KW.
- Input voltage: 480/277V, 400/230V, 380/220V
- Input range: +15%~-20%of Nominal Voltage.
- Input power factor >0.99.
- Current Total Harmonic Distortion <5%.
- Output voltage 350/380/400Vdc (Nominal).
- Current balance accuracy < 3%.
- Output Voltage regulation < 1%
- Output short current limit: 75A.
- AC – DC efficiency : 96%.
- Fully DSP based digital control.
- Delta patented topology for 3 phase buck boost PFC.
- Swappable power module design .
- Dimension: 129(H) x 219(W) x 700(D) mm.
- Weight: 16.1 Kg

Data Center DC Product Examples

380VDC Power Supplies, Interconnect Cables, Bus Ways, Outlet Strips, Breakers



480 – 208Y/120 VAC System Cost Comparison Diagram



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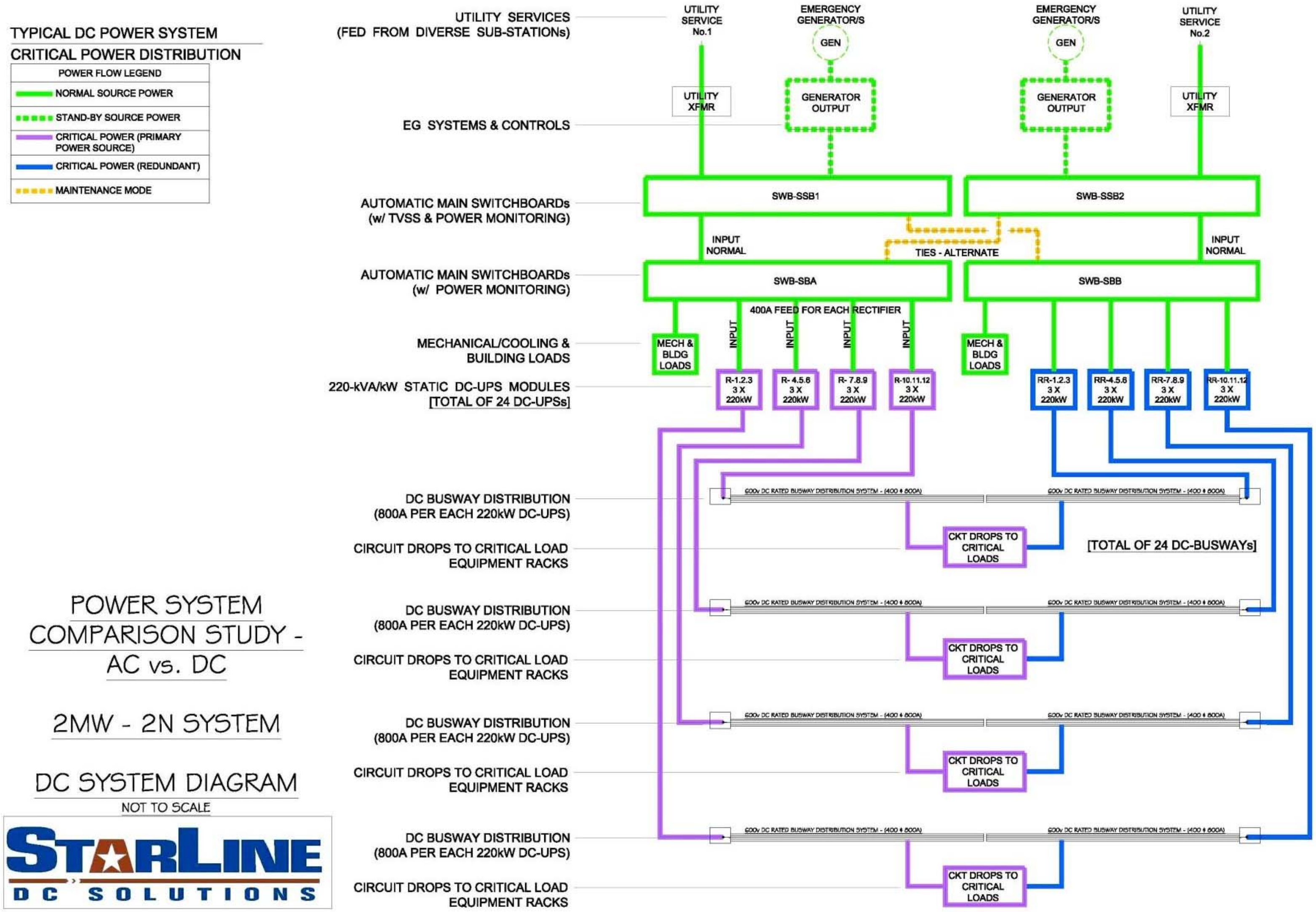
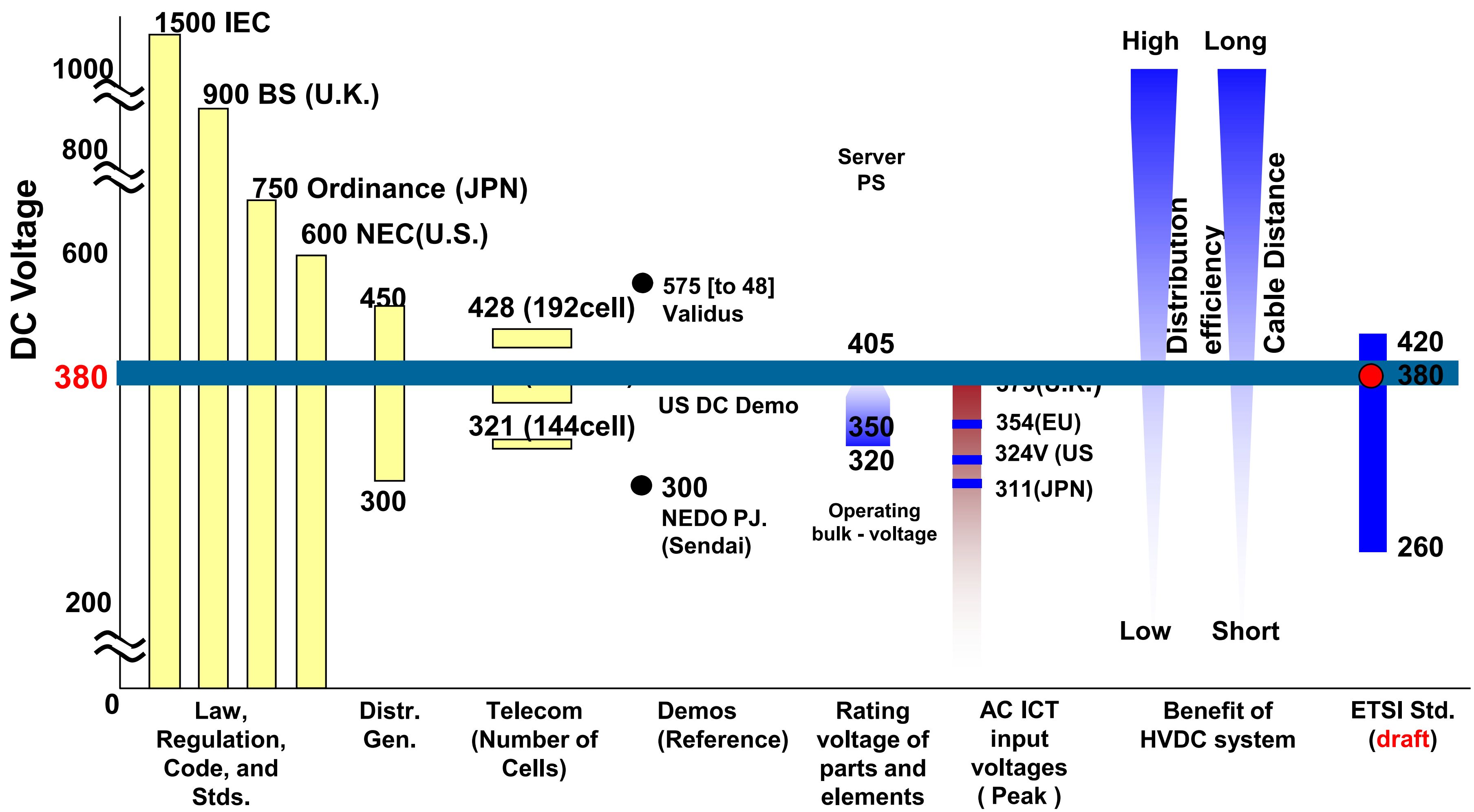
380 VDC System Cost Comparison Diagram

(15% Less CAP-EX and 35% Less OP-EX)

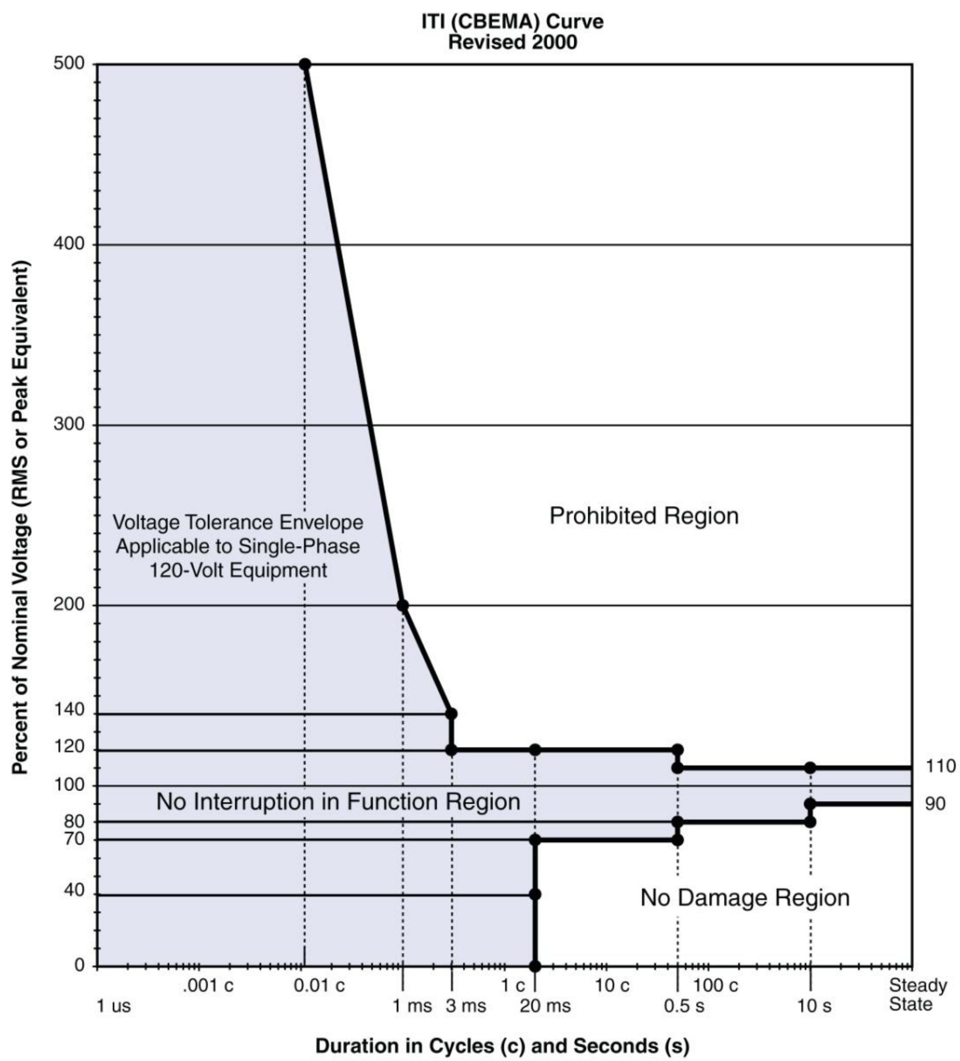


Why 380VDC? – "Sweet Spot"

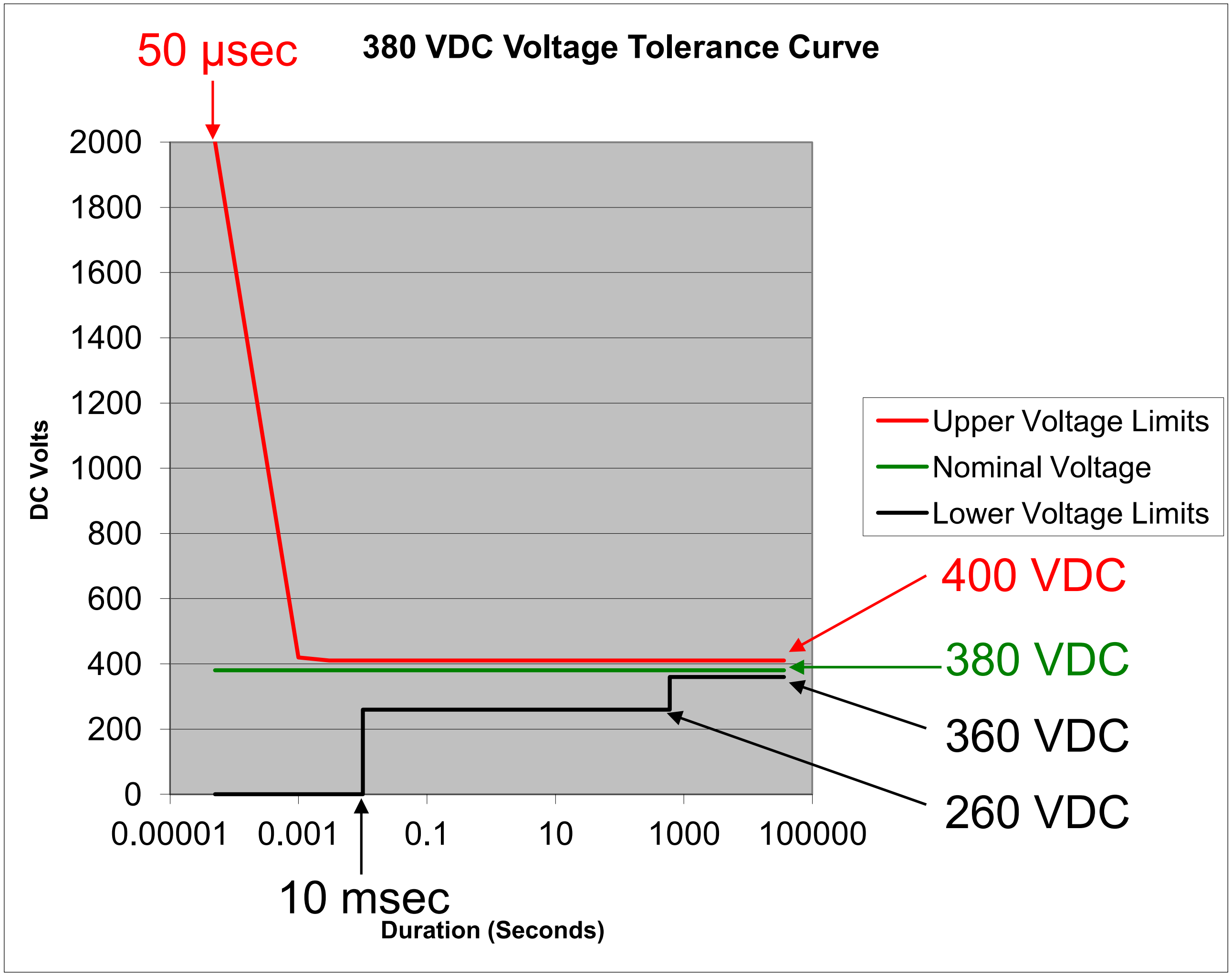


Edited from source: NTT FACILITIES, INC.

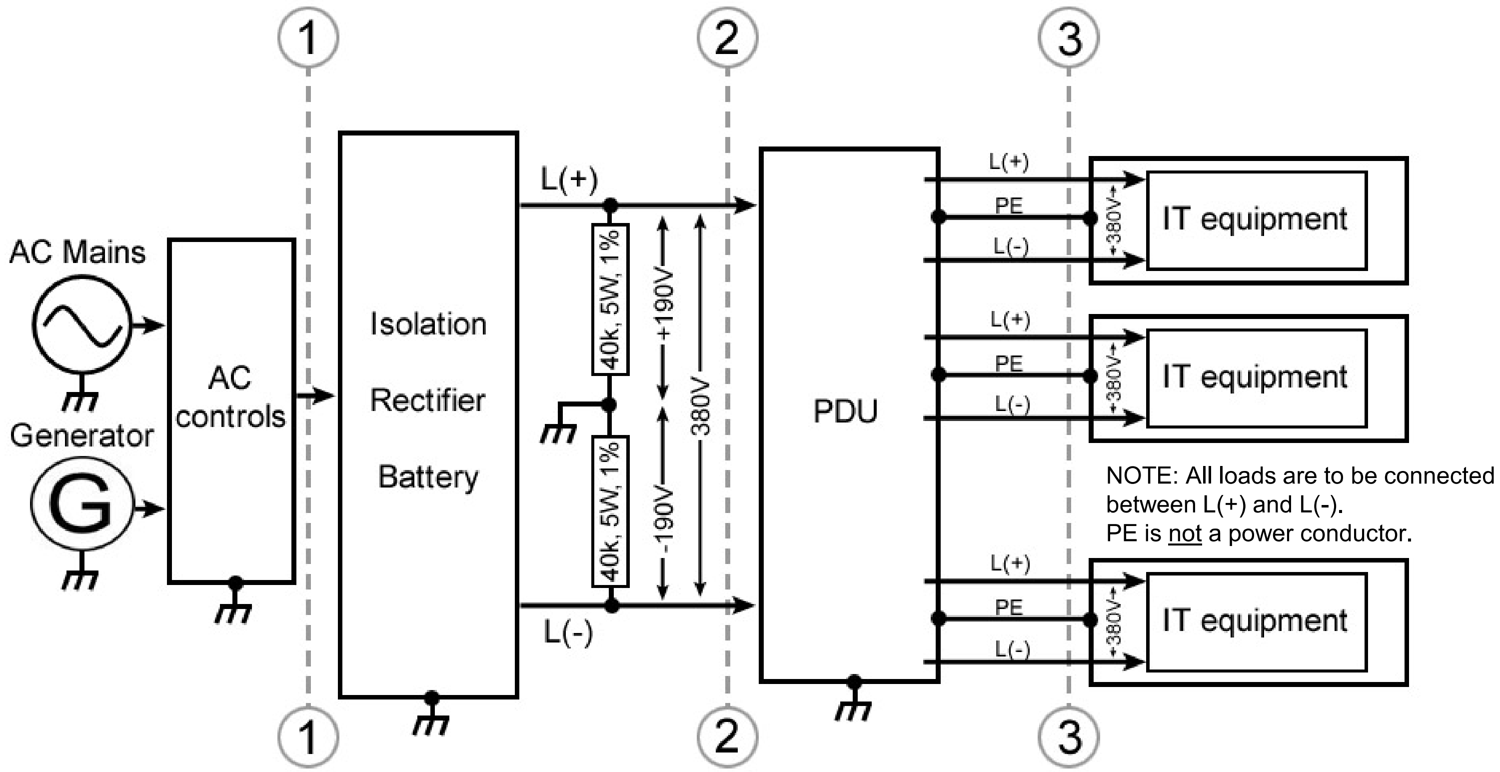
ITI(CBEMA) VAC Operating Ranges



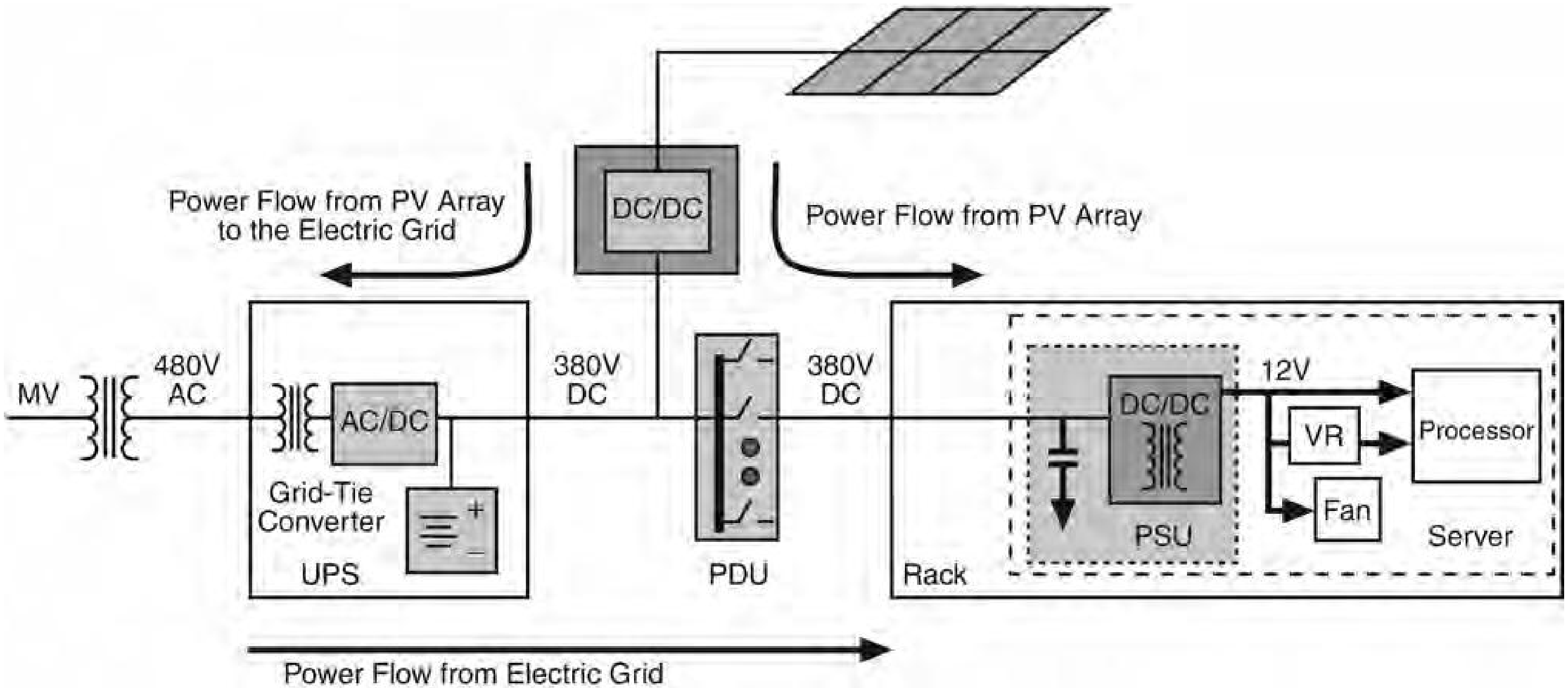
380VDC Operating Range



380VDC Power Distribution



Easier Integration Of Renewables



Reference to Nextek Power Systems US Patent 7,872,375 18JAN2011

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Benefits Summary Of 380VDC

- Higher Reliability
  - Fewer Conversions/Fewer Points Of Failure
- Higher Efficiency
  - Higher Efficiency Power Supplies & UPS
  - No PDU Transformer Needed
- Smaller Size
- Better Power Quality
- Easier Integration Of Renewable Energy
- Easier Integration of Energy Storage

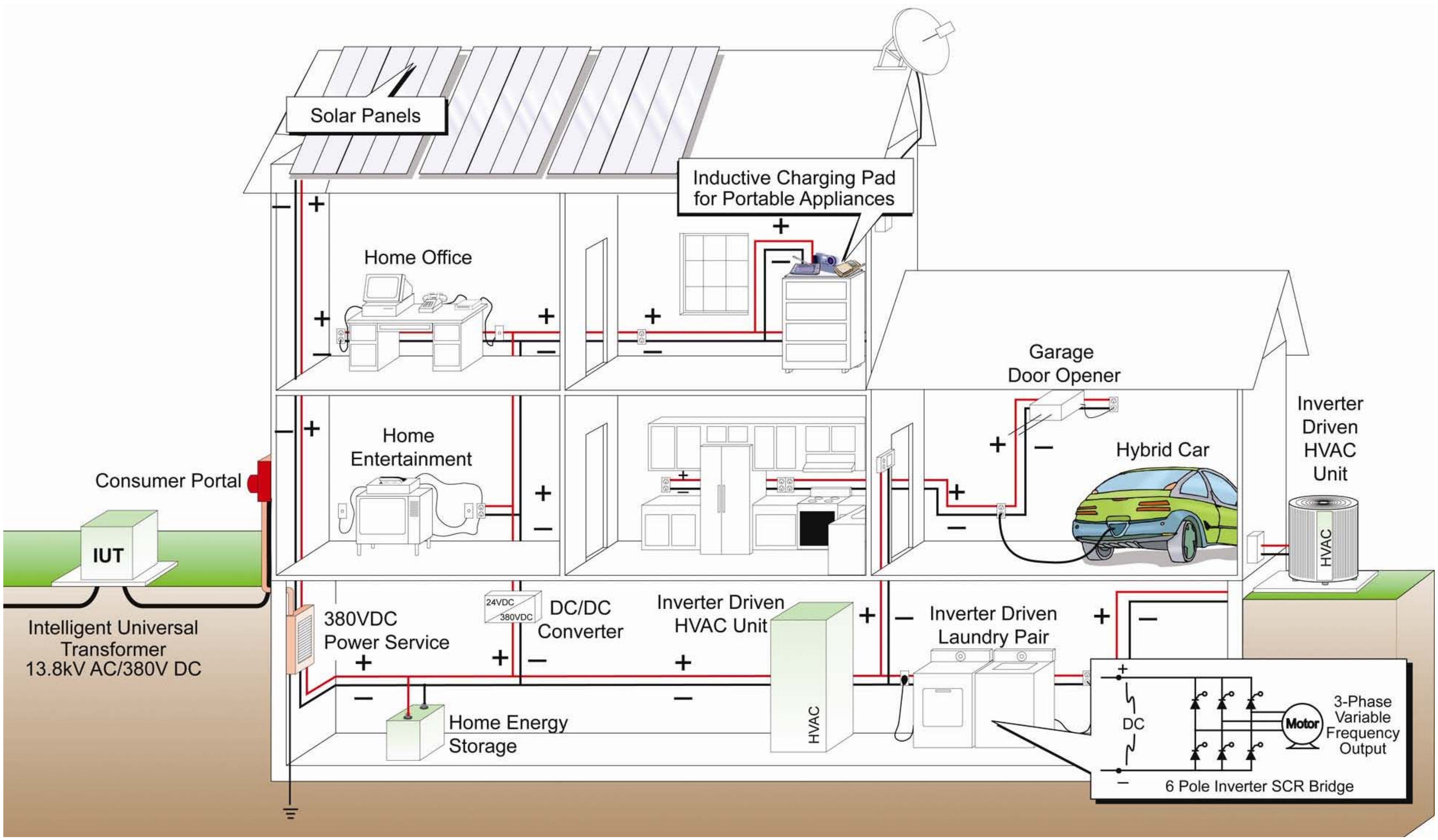
Other DC Applications

- 380VDC Uses
  - Telecom Central Offices (Operating Today At 48VDC)
  - Variable Speed Drives (Washers/Dryers/Air Cond)
  - Other Home Appliances (Stoves/Ovens)
  - “Rapid Charger” For Plug-in Electric Vehicles
- 24VDC Uses
  - Lighting
  - Consumer Electronics (TVs, PCs, Projectors)
- EMerge Alliance Members Working On Both Voltages

DC Challenges

- Standardizing on DC Voltages
  - 24VDC & 380VDC looking like leading candidates
- Safety Agency Approval/Listing (e.g. UL)
  - DC & AC Products Both Need These Approvals
- Paradigm Shift
  - Back To Some Of Thomas Edison's DC Ideas
  - We Are Used To The "AC" World Today
- Vendor Selection
  - Many AC Vendors To Choose From
  - Fewer DC Vendors Available --- At Least For Now

DC-Powered Home - Fantasy or Future Reality?



DC-Powered Home - Fantasy or Future Reality?

- My own home already has many DC-Powered products with “external” power supplies:
  - My Laptop Computer (20 V – 4.5 A)
  - My Cell Phone (5 V – 550 mA)
  - My Wife’s Cell Phone (5 V – 350 mA)
  - 4 Wireless Phones (6.5 V – 500 mA)
  - Wireless Internet Router (5 V – 2.5 A)
  - 2 Cable Modems (12 V – 750 mA)
  - Electric Razor (12 V – 400 mA)
  - Powered USB Port (5 V – 3.8 A)
  - Battery Operated Vacuum Cleaner (10 V – 250 mA)

DC-Powered Home - Fantasy or Future Reality?

- My own home already has many DC-Powered products with “internal” power supplies:
  - BlueRay DVD Player (26 W)
  - 2 Cable Set-Top Boxes (4.2 A)
  - Bose Home Theatre System (300 W)
  - 54” Plasma TV (465 W)
  - 36” LCD TV (175 W)
  - PC Mini-Tower (6 A)
  - 19” LCD Display (1.2 A)

DC-Powered Home - Fantasy or Future Reality?

- My own home also has many BIG AC-Powered loads:
- (I've already got two voltages in my house 120&240 VAC)
  - Microwave Oven (240 V – 8.3 kW)
  - Dishwasher (120 V – 11 A)
  - Toaster (120 V – 1050 W)
  - Coffee Pot (120 V – 1100 W)
  - Clothes Washer (120 V – 7 A)
  - Electric Clothes Drier (240 V – 5600 W)
  - Refrigerator (120 V – 8.3 A)
  - Electric Cook-top (240 V – 8.8 kW)
  - Electric Oven (240 V – 3600 W)

Utility Opportunities

- Possible new revenue opportunities
- Energy efficiency for new data center customers
  - Reduce electrical costs anywhere from 10 – 30%
  - DC O&M costs are on average 65% less than AC
- Conversion opportunities for existing data center customers
  - Approximately 2.5 million small to medium data centers in the U.S.
  - Component "swap out", not a complete "rip & replace"

Utility Challenges

- Getting data center customers on board
  - Faced it with our test (decided to test our own facility)
  - Getting commitments
  - Ex. Charlotte/Meck 911 Facility “Too new tech?”

- Technology has to be proven, both in concept and financial feasibility
  - Able to preliminarily show test results in the Duke Energy facility
  - Conversions for brownfield sites key aspect of potential success

Potential Outcomes

- Based on preliminary results in the Duke Energy facility (which showed over 15% increase in efficiency)
  - Average small to medium data center consumes approximately 0.5 to 5 MW
  - Reduction possibilities of 10 to 30%
  - Major impact for these data centers that are not “enterprise” sized
- Reinforces commitments to energy efficiency
- Provides new opportunities to interact with customers to provide wider range of products/services

Together…Shaping the Future of Electricity