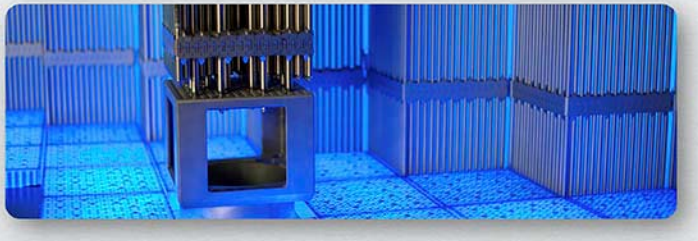



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DC Power Standards

Brian Fortenbery
Energy Efficiency Group
Power Delivery and Utilization Sector
EPRI

Data Center Power Delivery System

UPS
85 - 92%

Power Dist
98 - 99%

Power Supply
68 - 72%

DC/DC
78 - 85%

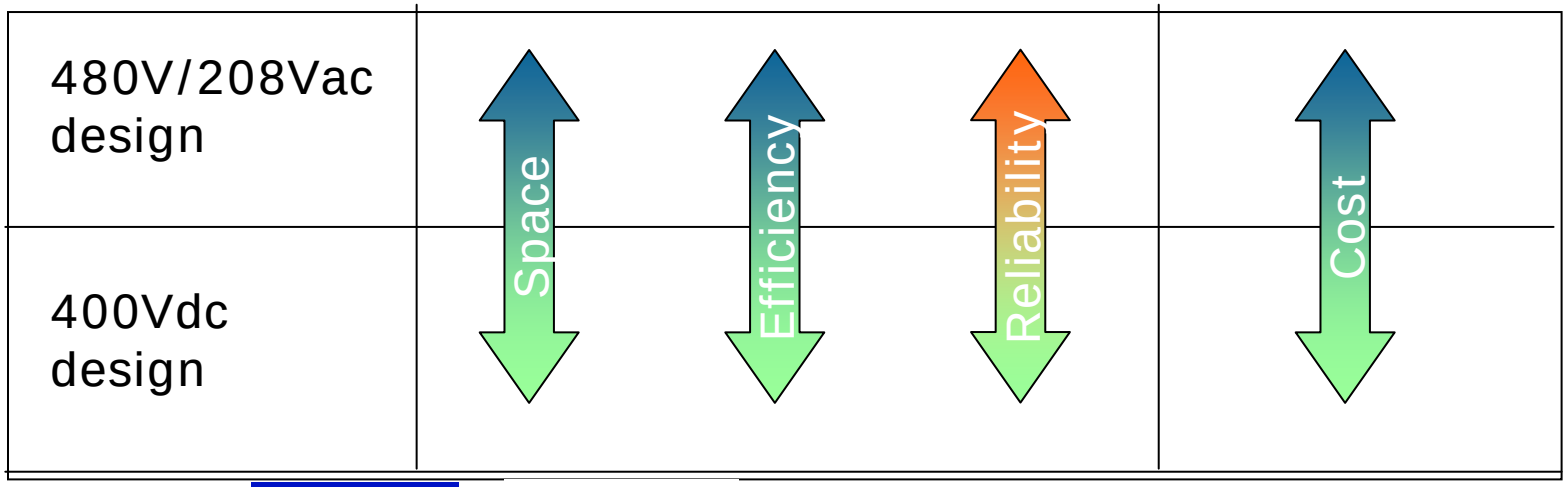
The heat generated from the losses at each step of power conversion requires additional cooling power

HVAC: Additional Power Loss for Cooling

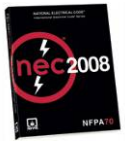
DC Demo Results

Comparison summary

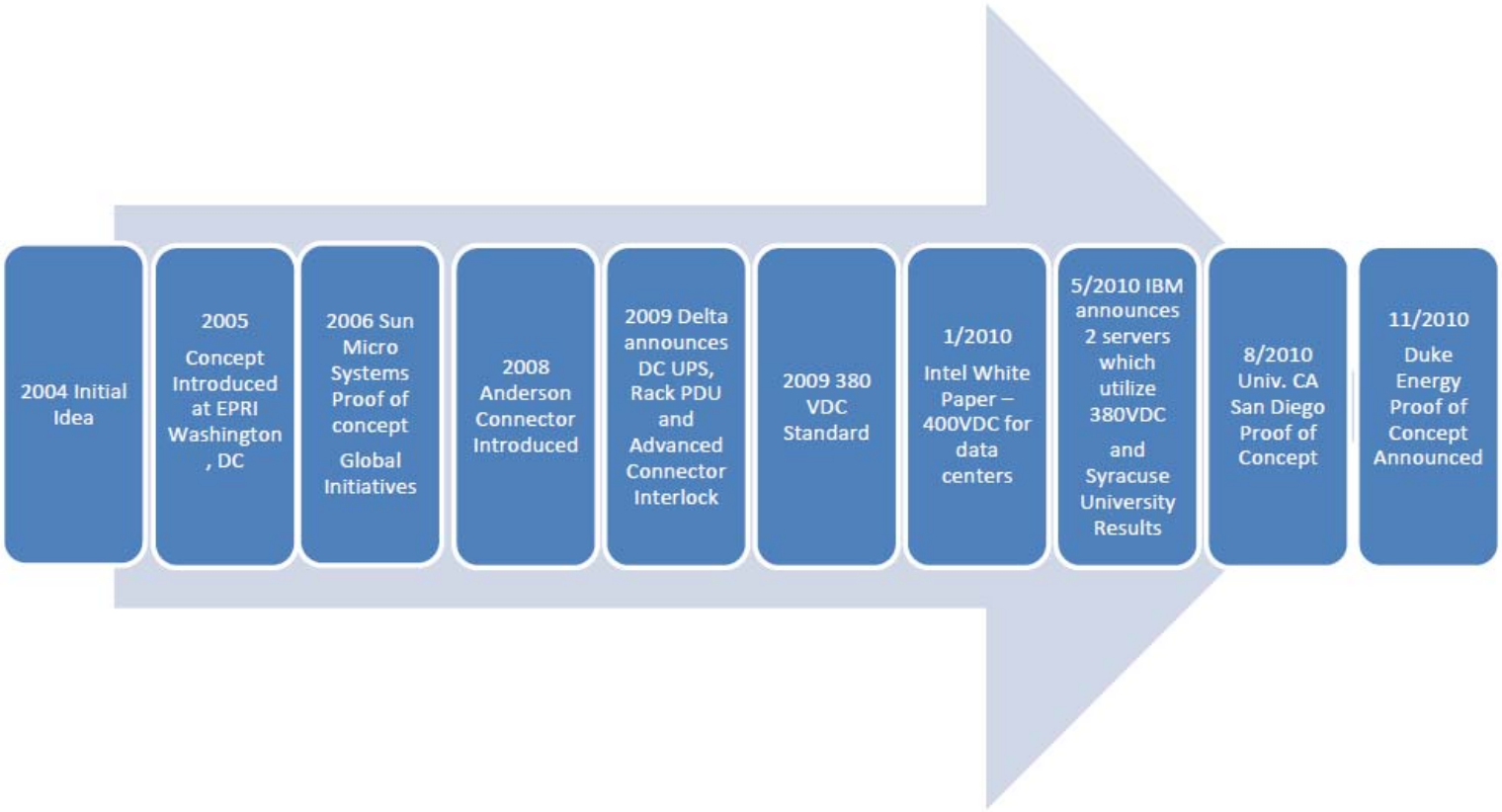
- Comparison for Intel facility shows** :
  - ~7% Facility energy savings, incl. cooling
    - 7.7% at 50% load; 6.9% at 80% load
  - 33% Space Savings
    - No PDUs, simplified switchgear
  - 200% Reliability improvement
    - 2x lower probability of failure in 5 years
  - 15% Electrical facility capital cost savings
    - Electrical is ~40% of total facility cost, i.e. saves 15% of 40% ~ 6% of total



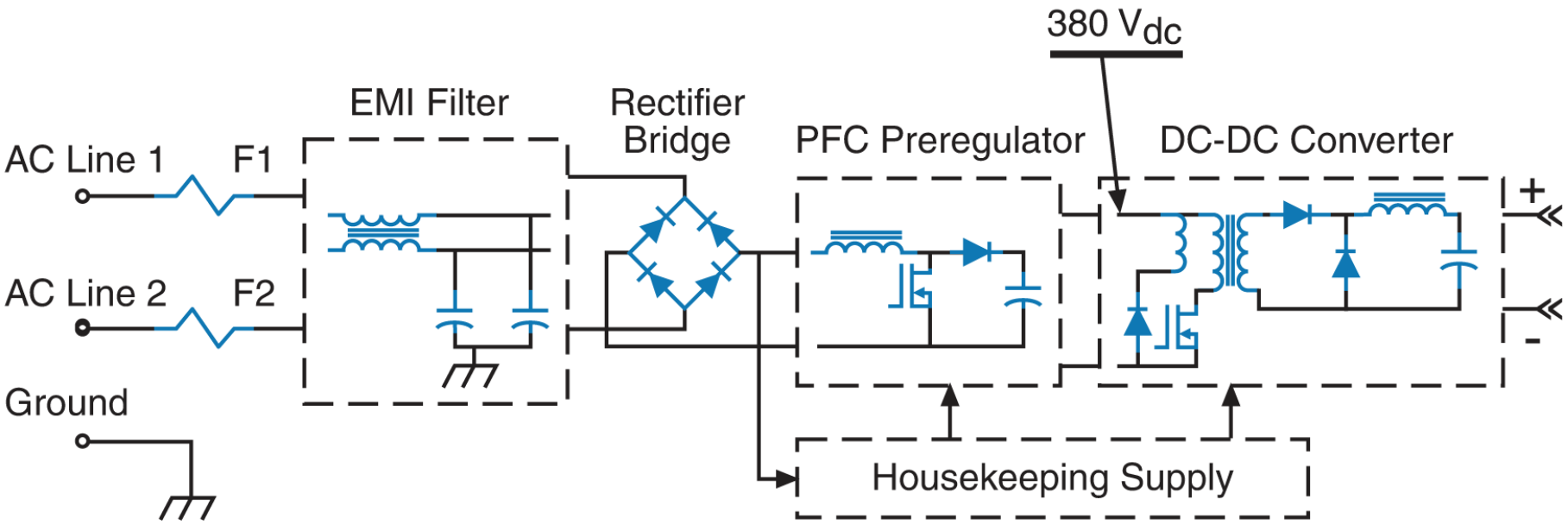
DC Power Partners



Historical Perspective

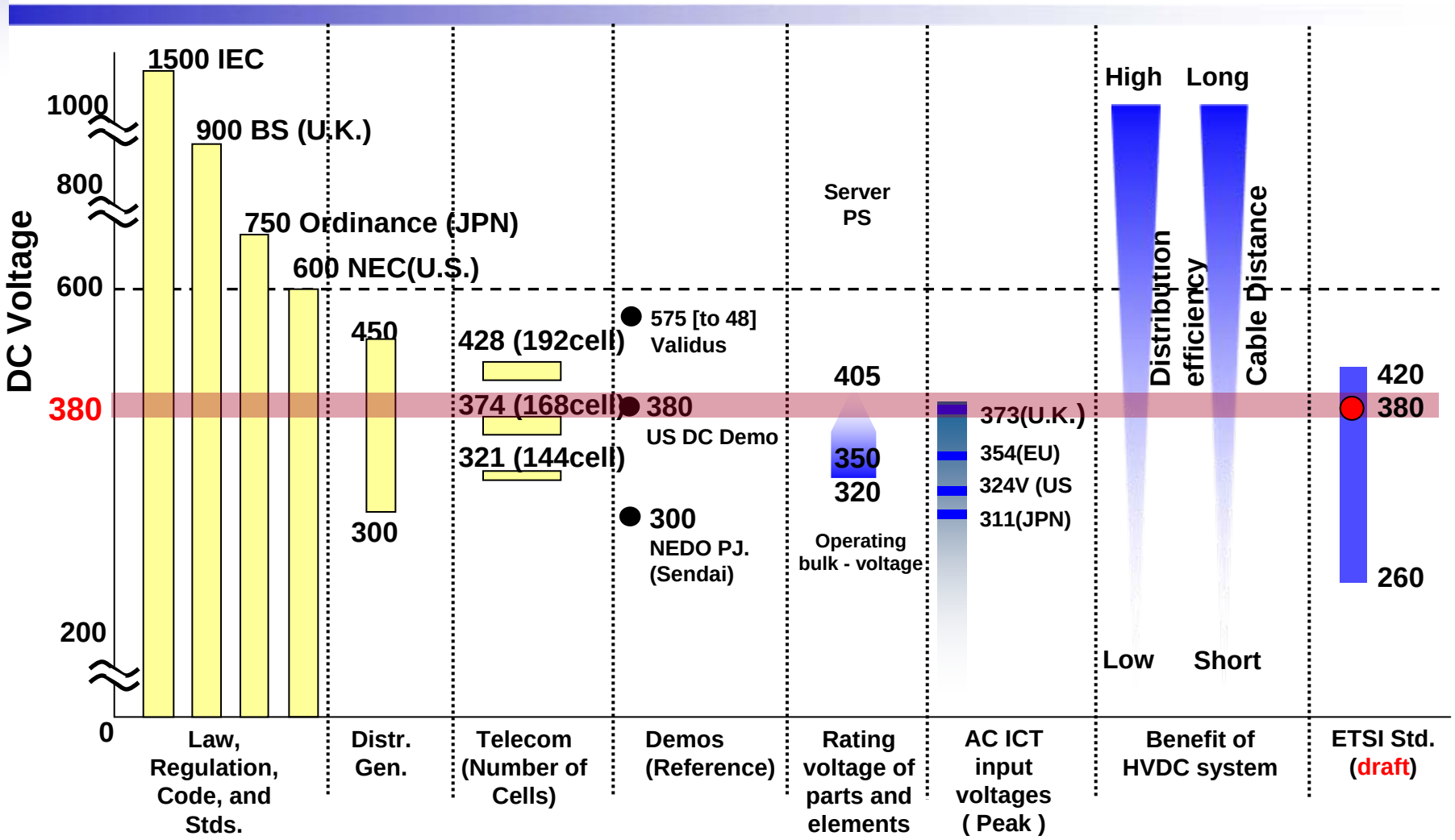


Power Supply Architecture



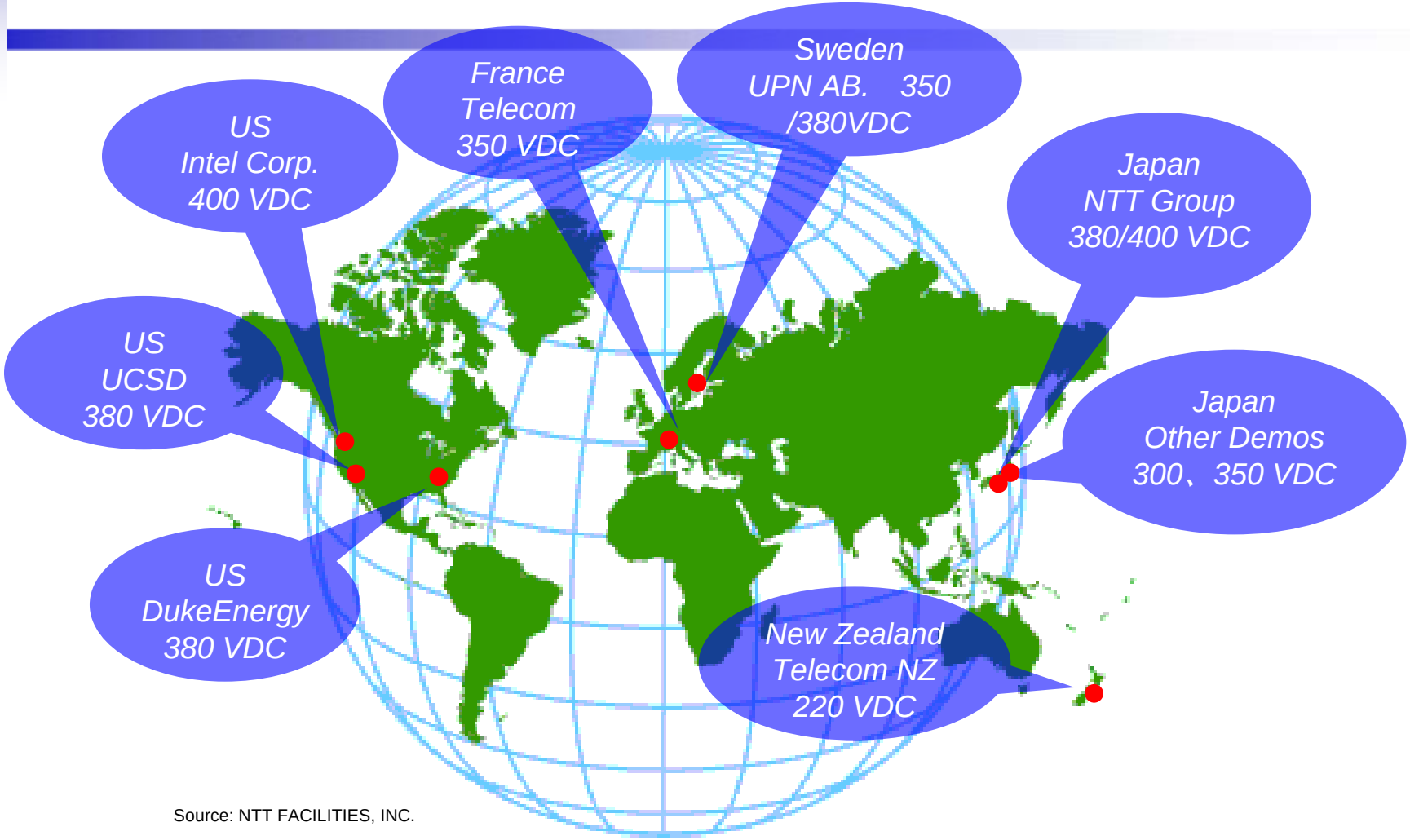
- **Mostly 200-240VAC**
- **Using 380VDC won't require re-layout of the printed circuit boards**
- **Safety & EMC & Power Quality requirement remain exactly the same**
- **Input connector must be changed to 380VDC rating**
- **Input voltage changes from 200-240VAC to 260-385VDC**

Why 380VDC? – “Sweet Spot”



Edited from source: NTT FACILITIES, INC.

Worldwide ~380VDC Demos



Source: NTT FACILITIES, INC.

DCPP Merges with eMerge Alliance

Organizations Join the EMerge Alliance to:

- Influence the development of standards for scalable use of safe, low-voltage DC power in commercial buildings and data or telecom centers
- Gain early access to the standard and its specifications for faster registration of products and services

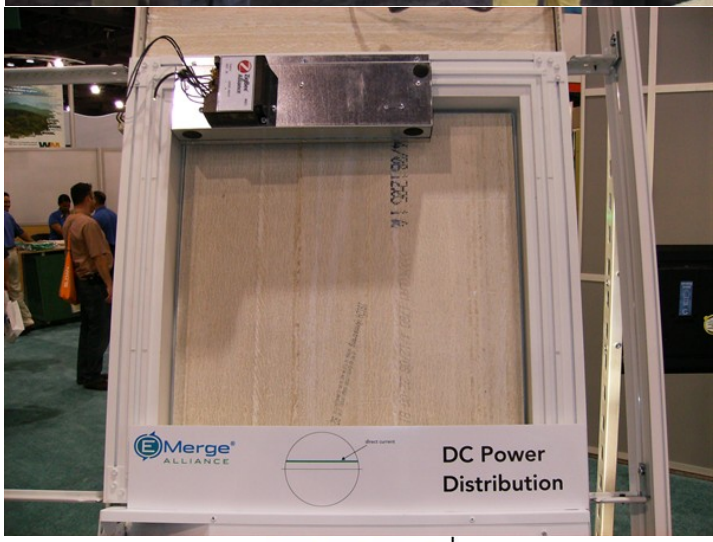
Who Is EMerge?

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

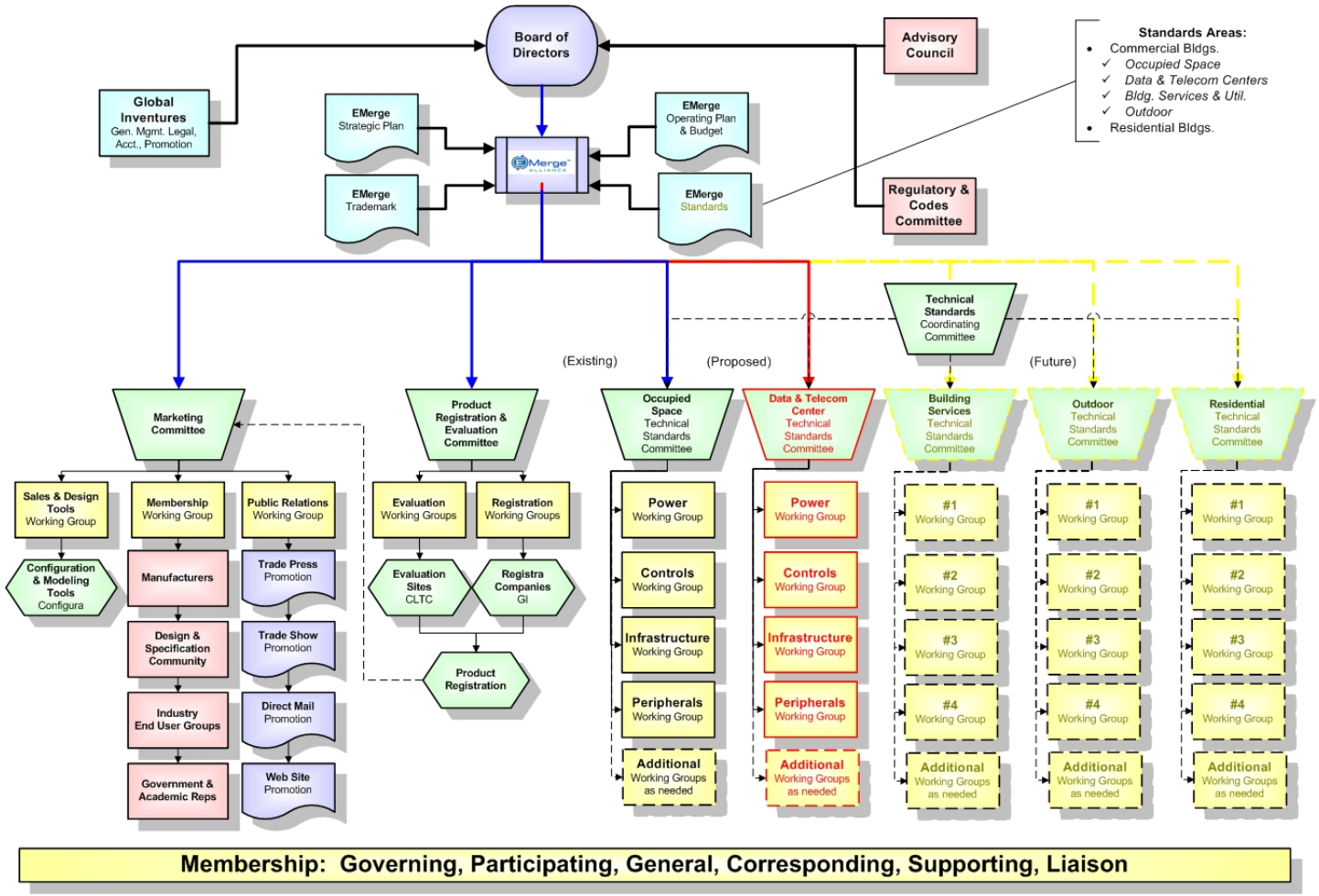
Emerge History

Highlights

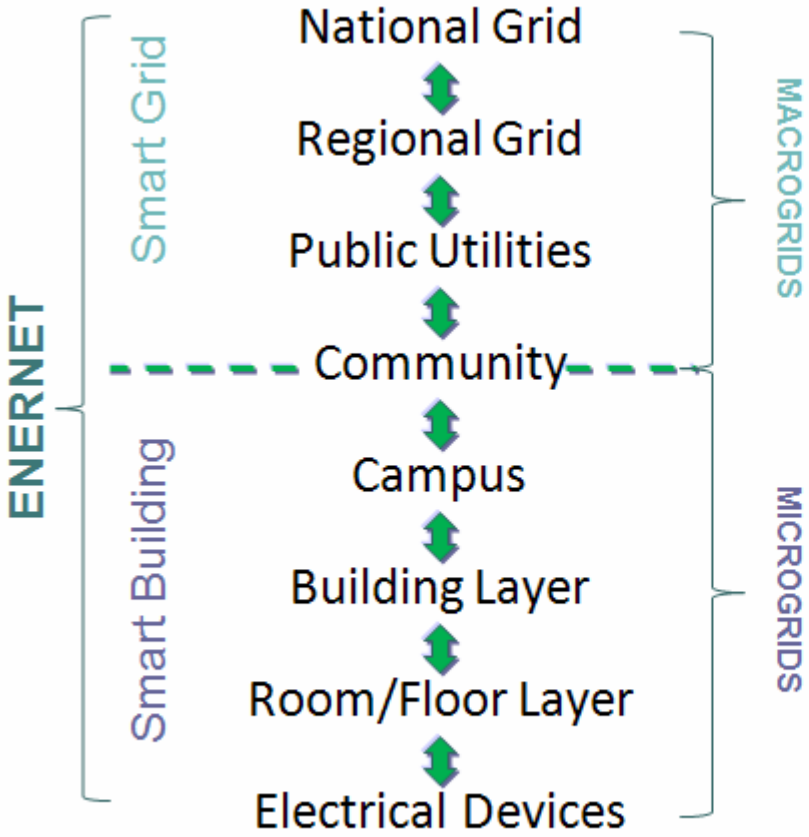
- EMerge Alliance Non-profit Incorporated: August 2008
- Open to Industry Membership: September 2008
- Began Work on the Standards: December 2008
- Issued 1st Standard (Occ. Space): November 2009
- Surpassed 50 Company membership: December 2009
- Surpassed 75 Company membership: January 2011

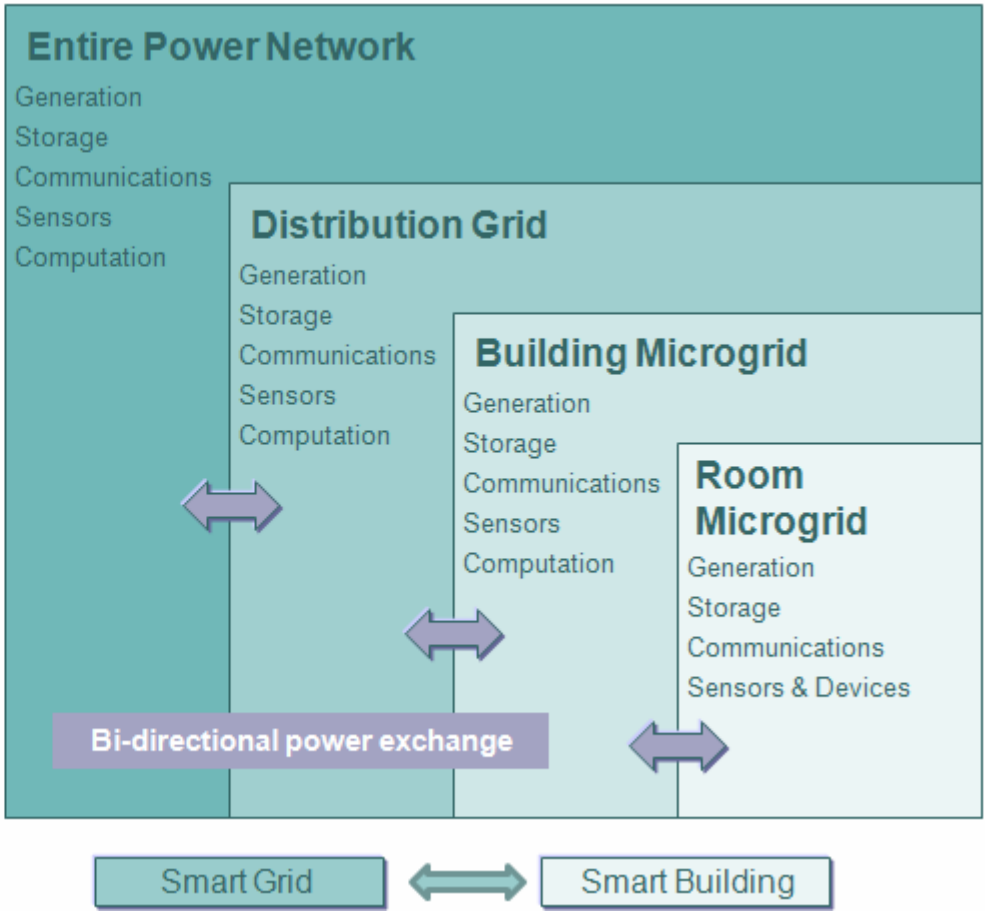


Growth of the Organization



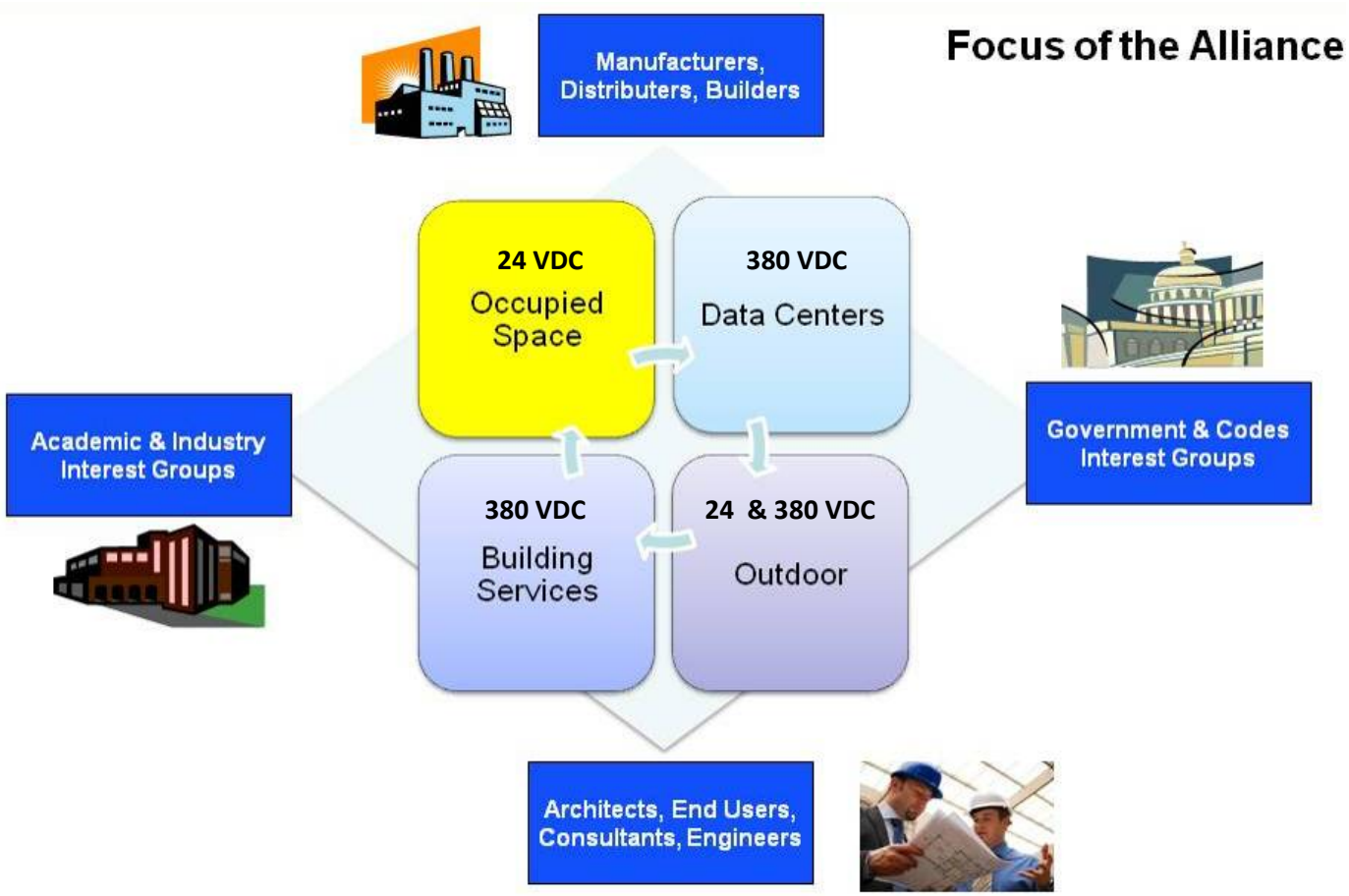
Smart Grid to Smart Buildings





Source: EMerge Alliance Overview

DC Microgrids Throughout Buildings



Source: EMerge Alliance Overview

EMerge Alliance Standard – 24VDC Ceiling View

INFRASTRUCTURE:

Ceiling

↓

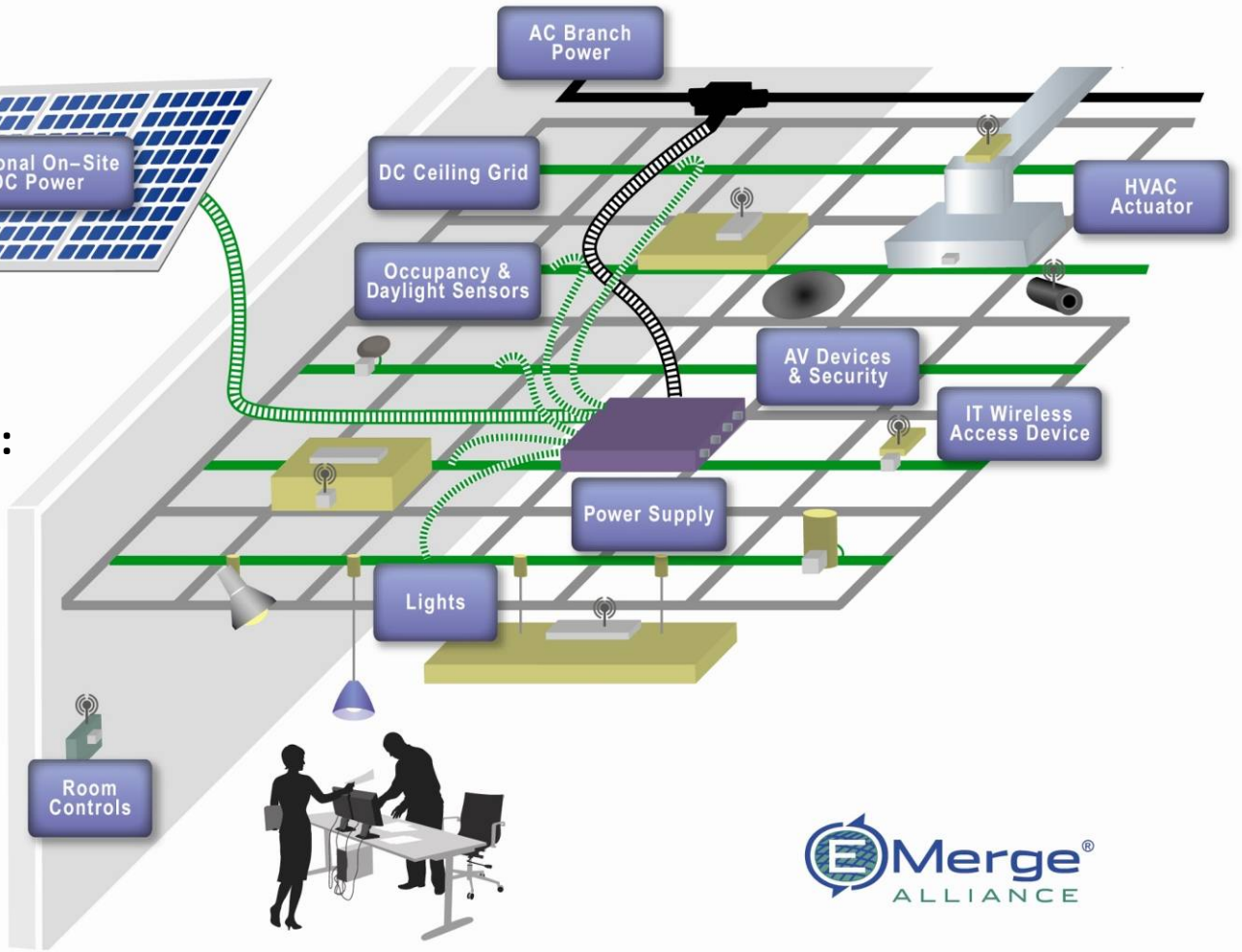
Walls

↓

Furniture

↓

Floors



EMerge® ALLIANCE

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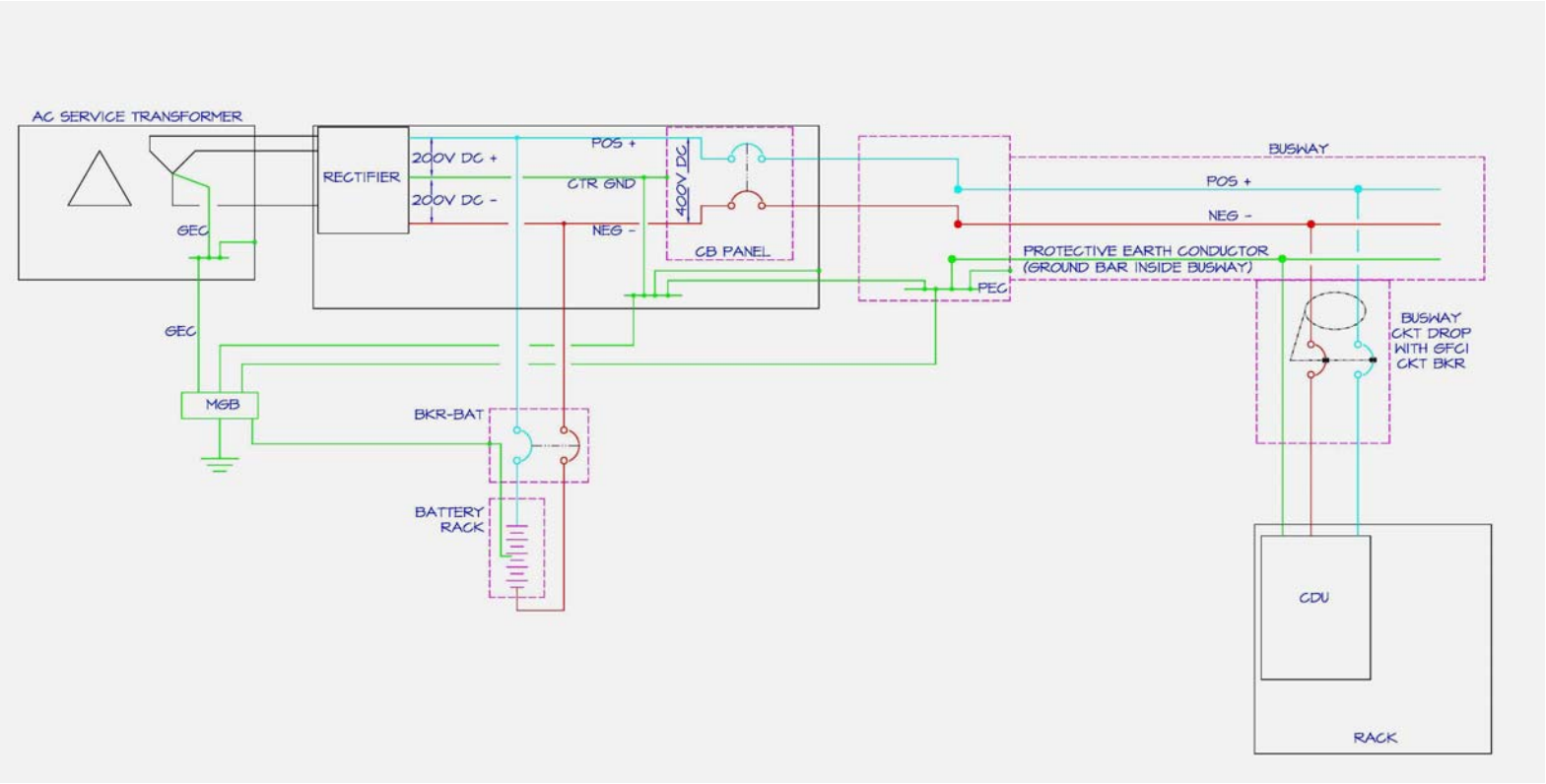
380 VDC Power Distribution Specification

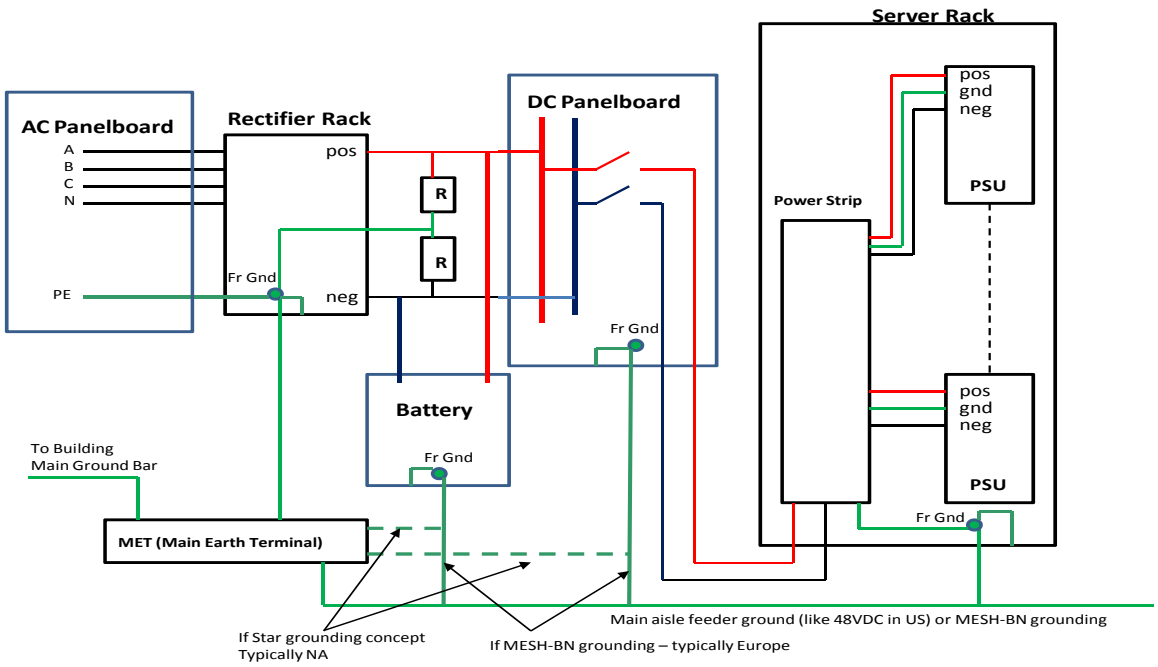
- Center point of rectifier is grounded, +/-190V
- Use std 3 pole device possible
  - Many manufacturers : ABB, Square D, GE



380 VDC Power Distribution Specification

380 VDC Grounding Concept

Typical Grounding for a 380VDC Resistive Center Ground System



1

EMERSON Network Power

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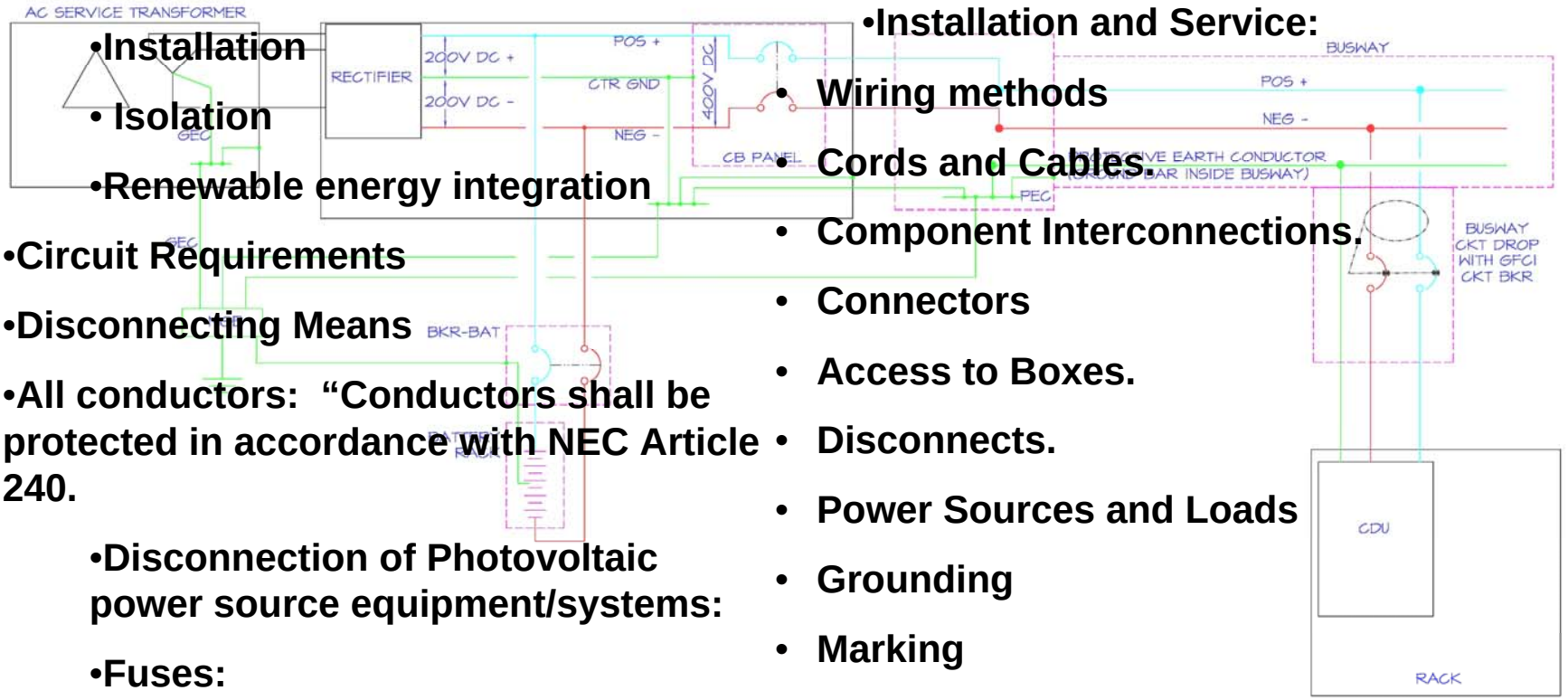
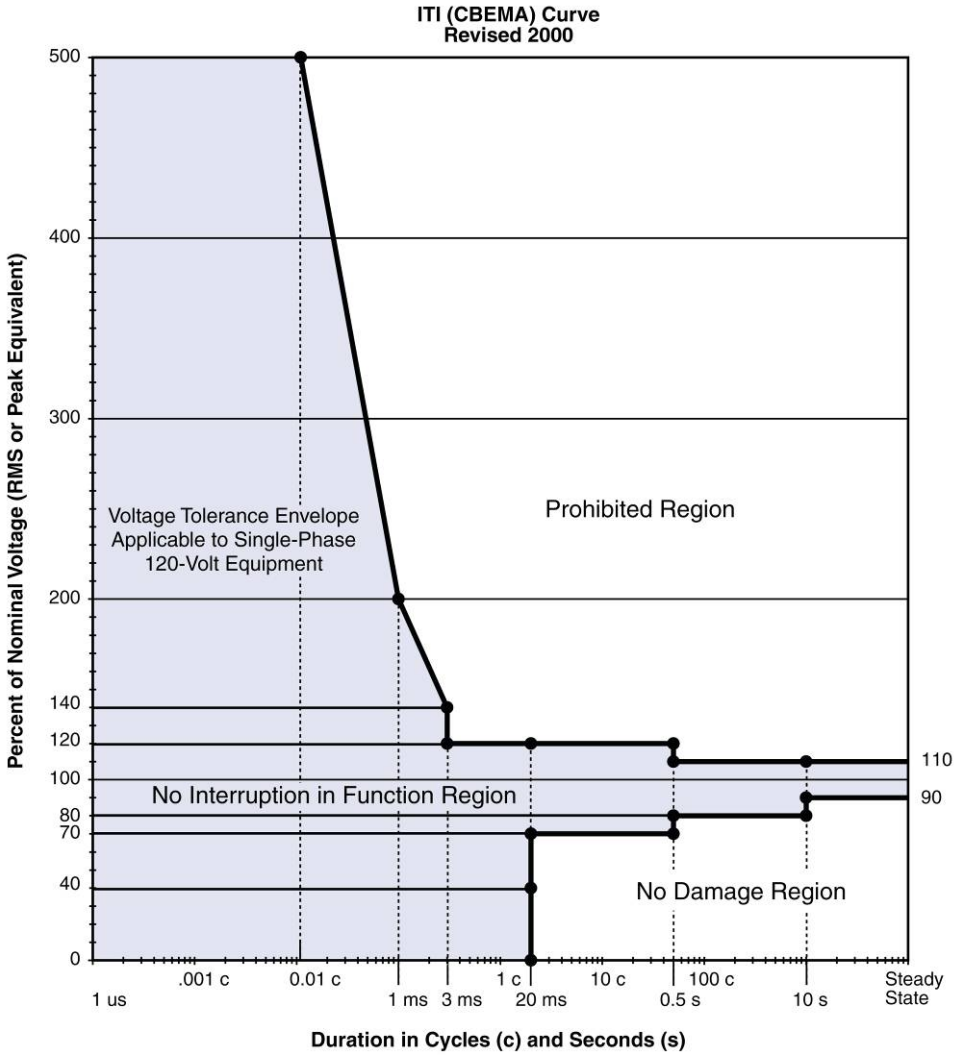
380 VDC Power Distribution Specification

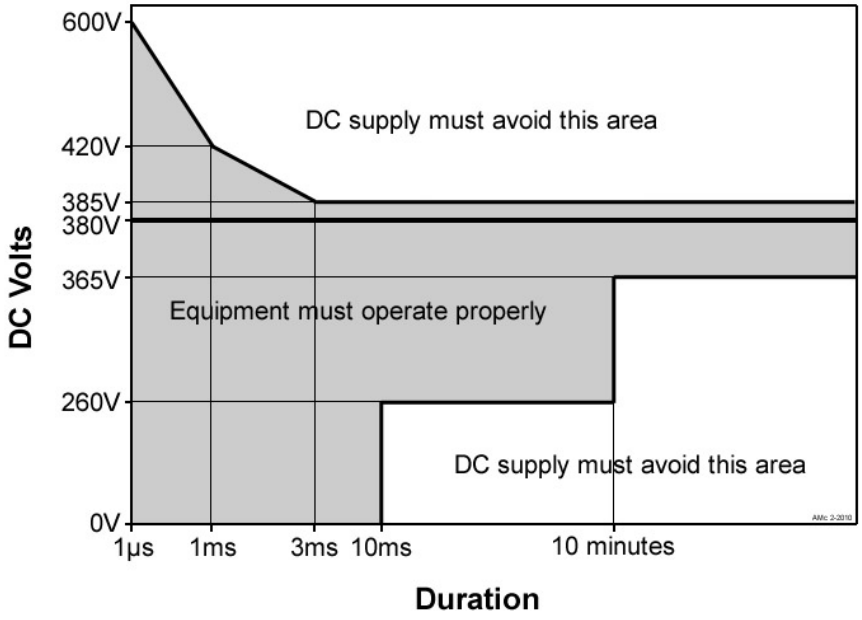


- •Installation
- • Isolation
- •Renewable energy integration
- •Circuit Requirements
- •Disconnecting Means
- •All conductors: “Conductors shall be protected in accordance with NEC Article 240.
  - •Disconnection of Photovoltaic power source equipment/systems:
  - •Fuses:
  - •Switch or Circuit Breakers:
  - •Ground-Fault Protection:

- •Installation and Service:
- Wiring methods
- Cords and Cables.
- Component Interconnections.
- Connectors
- Access to Boxes.
- Disconnects.
- Power Sources and Loads
- Grounding
- Marking
- Connection to Other Sources
- Controls & metering
- Energy Storage

380VDC vs ITI(CBEMA) VAC Operating Ranges





- Voltage Tolerance Envelope for traditional AC powered computers (left)
- New, DC version of curve, developed by EPRI with NTT and PSL (right)

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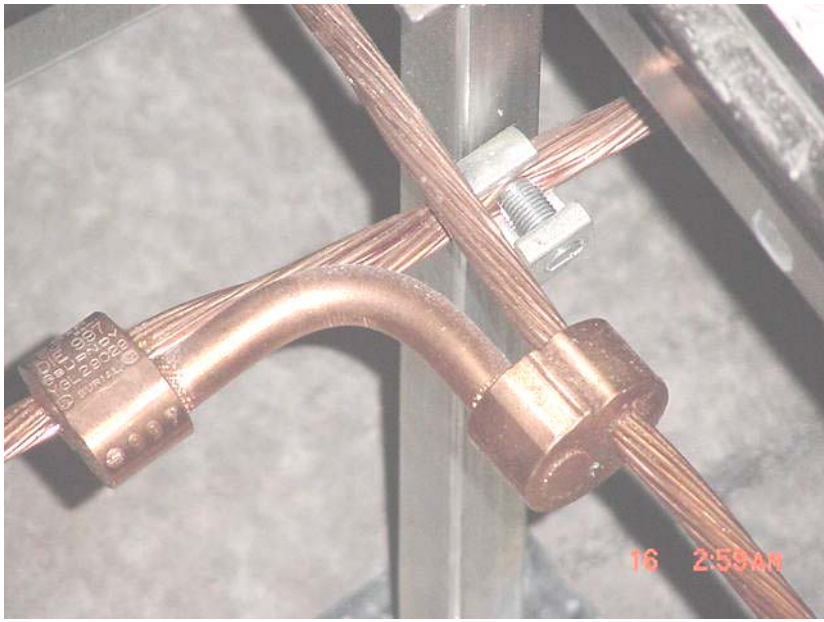
380VDC Electrical Characteristics (New Rules and Grounding)

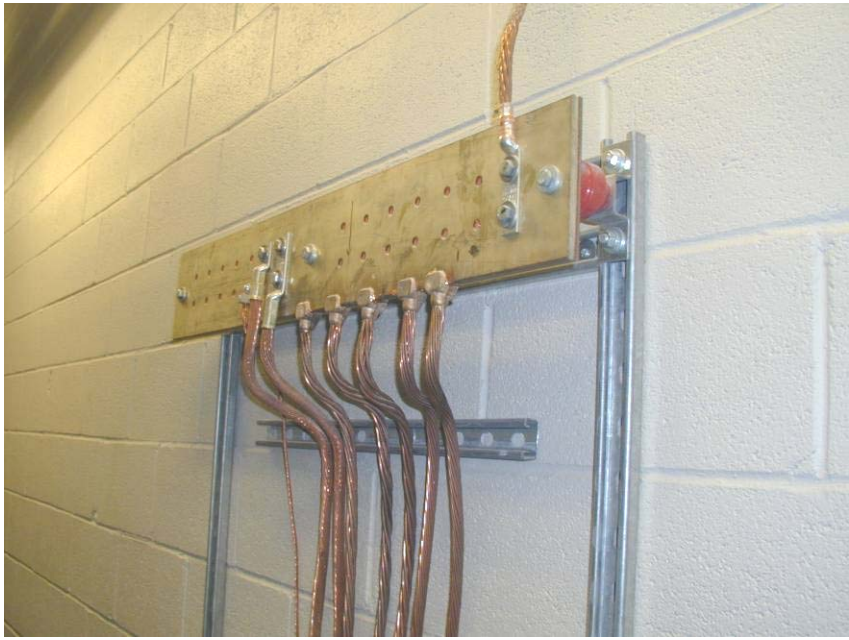
- Emissions of radio-frequency radiated & conducted disturbances limited per IEC/CISPR 22 Class A levels
- Immunity from power quality transients per IEC/CISPR 24
- Ripple noise to be limited to 1V (peak-to-peak) per JEITA RC-9130B
- All connectors shall have built-in arc-flash prevention measures
- All loads shall be protected against reversed polarity connection
- High Impedance Center Tapped Ground - Lower possibility of arc-flash issues



380 VDC Facilities Power Distribution

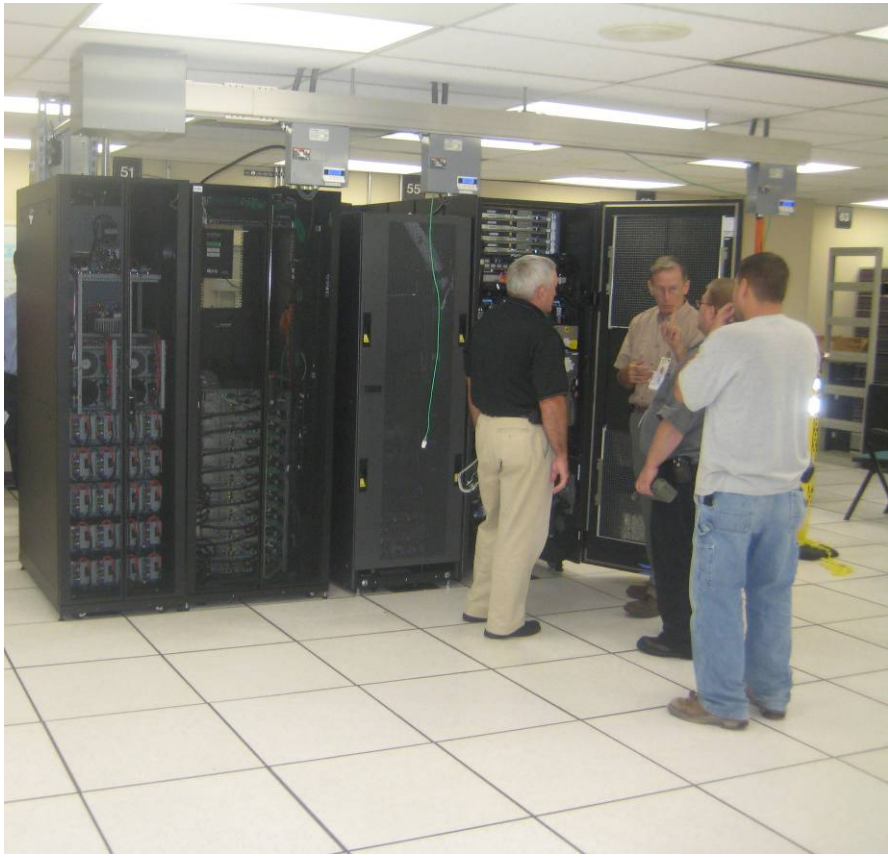
Facilities Specification

- **Need Safety Agency (e.g. UL) listing on all new 380 VDC products (Rectifier/DC UPS/PDU/Busway/Fuse/Breaker/Power Strip/Connectors)**
- **Electronic current limiting preferred over CB / fuse coordination**
- **Need global harmonization of connectors, protection and wiring standards for 400Vdc**
- **+/- 190 VDC rating (380 VDC Center-Tapped)**
- **All loads connected between +190 and -190 VDC**
- **No loads are to be connected +190 to ground or -190 VDC to ground**



380VDC Data Center Activity

- Involved With Multiple 380VDC Demos
  - Universities
  - Electric Utilities
  - Telecom Industry
- Harmonizing Multiple 380VDC Spec Efforts
  - DC Power Partners Joining EMerge Alliance
  - European Telecommunications Standards Institute
  - International Electrotechnical Commission (SG4)
- Working With Many Manufacturers
  - IT Equipment As Well As Facility Equipment



Duke Energy 380VDC Data Center Demo

HP Servers

IBM Servers

EMC Storage Arrays

Delta Rectifiers

StarLine Busway

Dranetz-BMI Metering

Duke Energy 380VDC Data Center Demo

HP Servers

IBM Servers

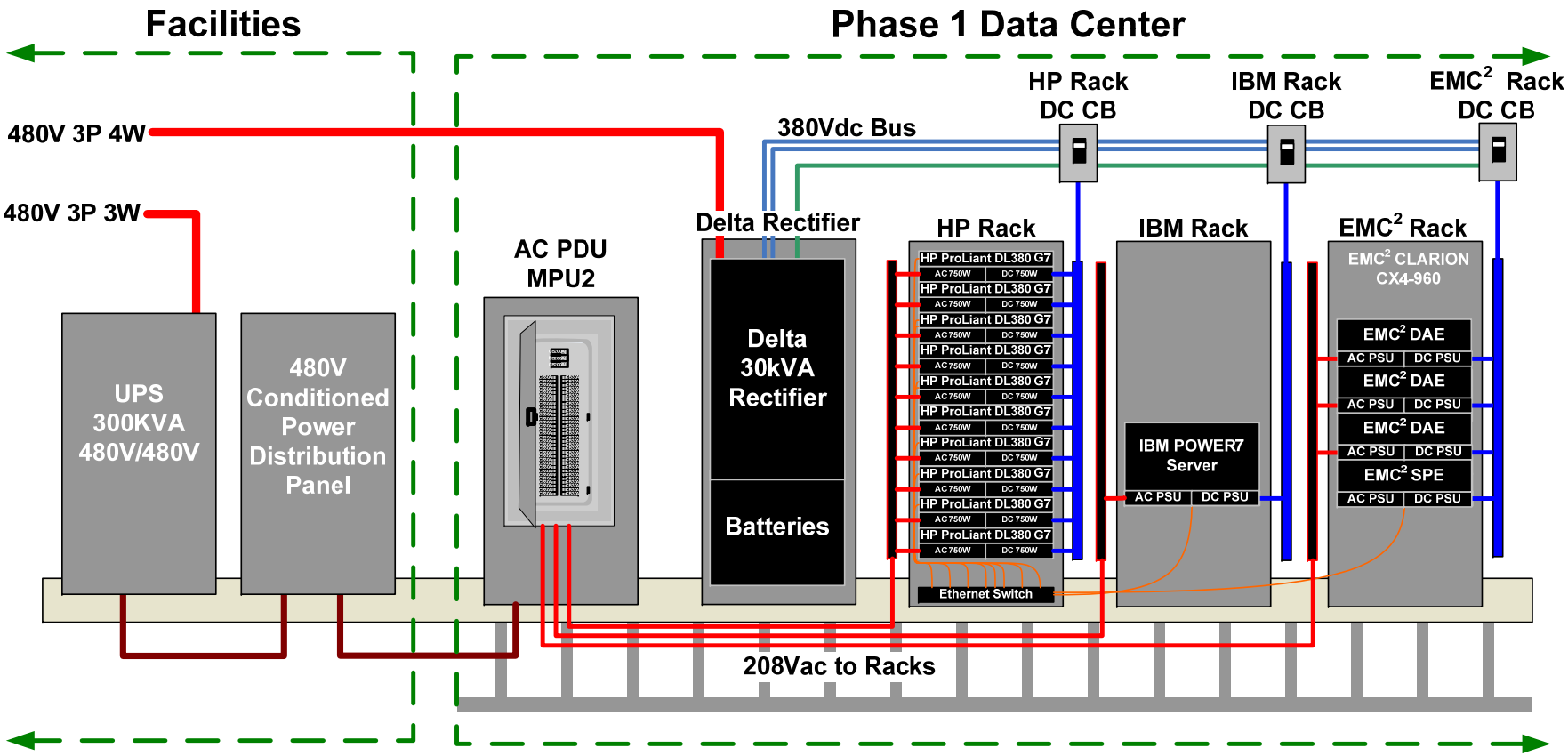
EMC Storage Arrays

Delta Rectifiers

StarLine Busway

Dranetz-BMI Metering

Duke Energy Data Center Set-Up



Measurement & Verification Plan

Duke Energy
Data Center Demonstration Project

DC and AC Power Network Efficiency Comparison
Measurement and Verification Plan
Draft

Duke Energy

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EPRI
Chuck Thomas

July12, 2010

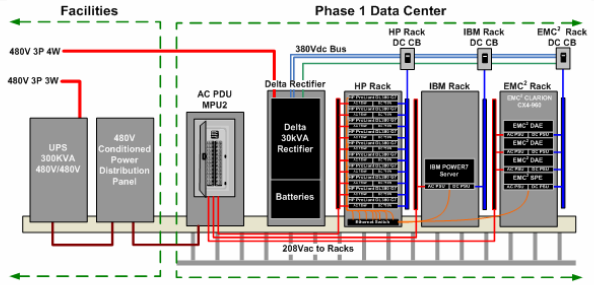


Figure 2 - AC and DC Network Components and Loads (HP, IBM and EMC2 Racks)

Lists of all test components are included in Table 1.

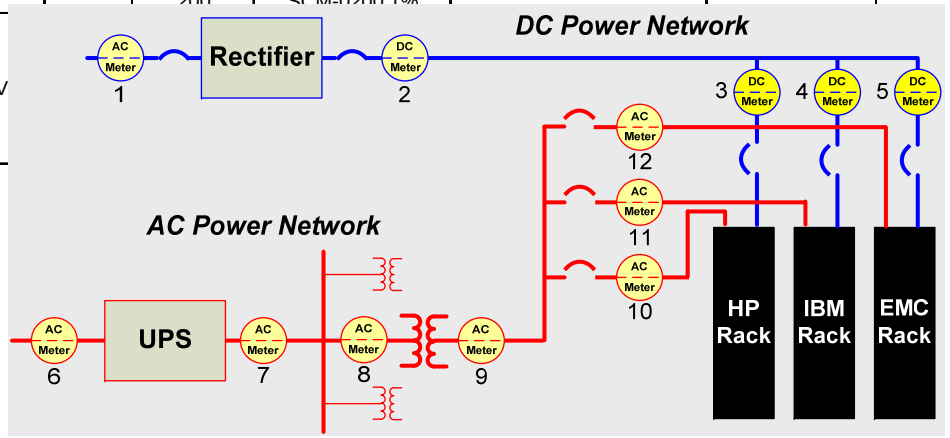
Table 1 – AC/DC Demonstration System Components (Font BOLD signifies existing systems, all other devices are new to the facility and this project)

Manufacturer	Description	Applicable Power System	Quantity	Model	Power Rating
Delta Products Corp	30kW 480VAC to 380VDC Rectifier	DC	1	30KW HVDC UPS	30kW
Liebert	**300kW UPS 480VAC to 480VAC Three-phase**	**AC**	**1**	**Series 610 UPS**	**300kW**
Liebert	**125kVA Data Center Power Distribution Unit**	**AC**	**1**	**PPA125C**	**125kW**
Hewlett Packard (HP)	ProLiant DL380 G7 Servers	Both	10	DL380G7	
Hewlett Packard (HP)	ProLiant DL380 G7 AC/DC Power Supply Unit (PSU)	AC	10	506821-001	750W
Hewlett Packard (HP)	ProLiant DL380 G7 DC/DC Power Supply Unit (PSU)	DC	10	506821-001	750W
IBM	POWER7 Server	Both	1	P7 (Exact Model ?)	
IBM	POWER7 AC/DC Power Supply Unit (Dual)	AC	2	?	
IBM	POWER7 DC/DC Power Supply Unit	AC	1	?	
EMC²	EMC² CLARION CX4-960 Networked Storage System	Both	1	CX4-960	
EMC²	EMC² CLARION CX4-960 SPE Unit	AC	1	SPE AC PSU	1570W

Measurement & Verification Plan

Table 10 – Field Monitoring Data Points

Circuit	Meter Number	Name	Location	Rated V	Load (KW)	CT / Shunt Rating	Current Measurement Instrument	Meter	Units of Measure
DC Rectifier Input	1	Rectifier_IN	Rectifier Input	480V	30	100	SCM-0100 1%	DENT Instruments Power Scout 3 Accuracy 1% (Typical <0.5%)	kW, kWh, V, I, Pf
						100	SCM-0100 1%		
						100	SCM-0100 1%		
Rectifier Output	2	Rectifier_OUT	Rectifier Output	380Vdc	30	100A /100mV	Empro 0.1% NIST	AccuEnergy AccuDC 223 Accuracy 0.2%	kW, kWh, V, I
HP Rack	3	HP_Rack_DC	Drops to each rack		3-5	30A/100mV	Empro 0.1% NIST	AccuEnergy AccuDC 223 Accuracy 0.2%	kW, kWh, V, I
EMC Rack	5	EMC_Rack_DC			3.00	30A/100mV	Empro 0.1% NIST	AccuEnergy AccuDC 223 Accuracy 0.2%	kW, kWh, V, I
IBM Rack	4	IBM_Rack_DC			10.00	30A/100mV	Empro 0.1% NIST	AccuEnergy AccuDC 223 Accuracy 0.2%	kW, kWh, V, I
UPS Input	6	UPS_IN	MDS Rm 123	480V	300	1000	SCL-1000 1%	DENT Instruments Power Scout 3 Accuracy 1% (Typical <0.5%)	kW, kWh, V, I, Pf
						1000	SCL-1000 1%		
						1000	SCL-1000 1%		
UPS Output	7	UPS_OUT	DP-3 Rm 123	480V	300	1000	SCL-1000 1%	DENT Instruments Power Scout 18 Accuracy 1% (Typical <0.5%)	kW, kWh, V, I, Pf
						1000	SCL-1000 1%		
						1000	SCL-1000 1%		
Transformer Input	8	XFMR_IN	DP-3 Rm 123	480V	125	200	SCM-0200 1%		
						200	SCM-0200 1%		
						200	SCM-0200 1%		
Transformer Output	9	XFMR_OUT	MPU2 Rm 220	208V					
HP Rack	10	HP_Rack							
EMC Rack	11	EMC_Rack							



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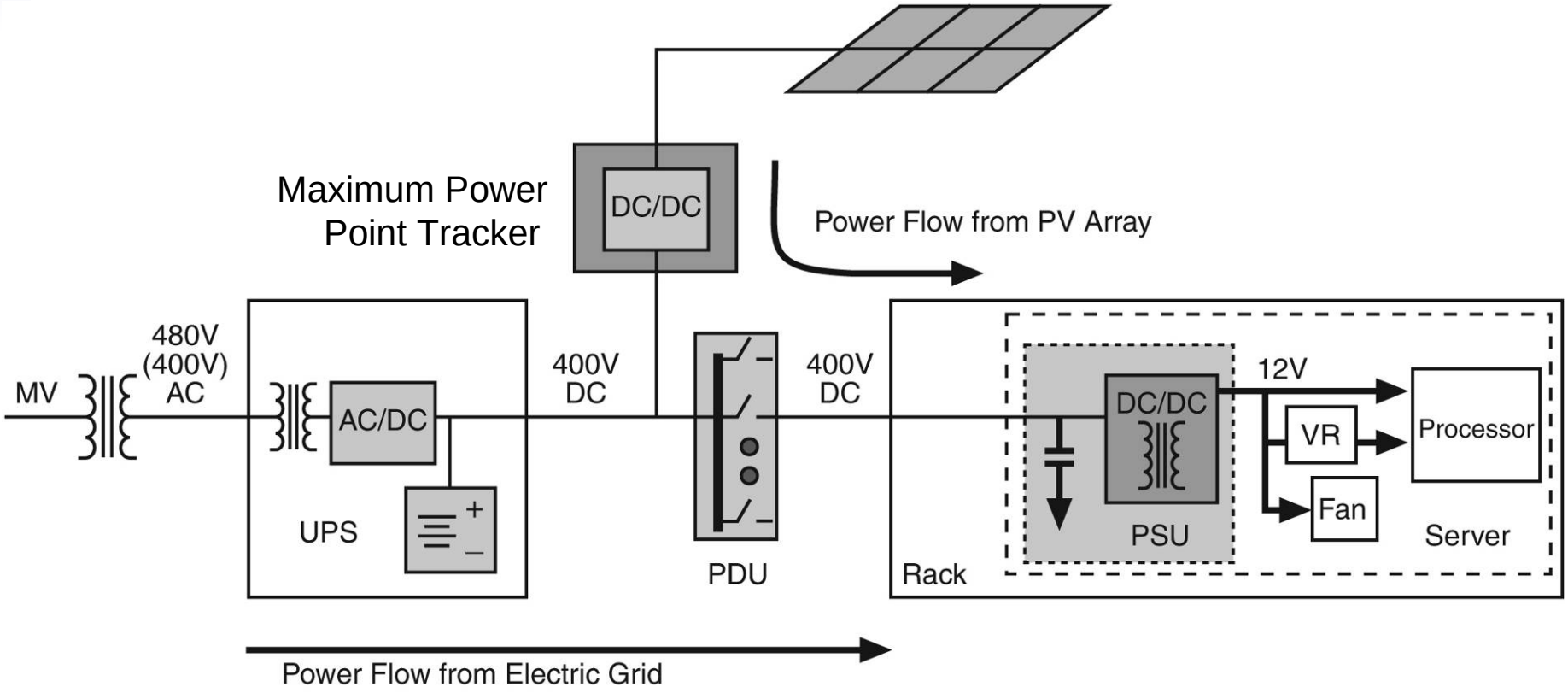
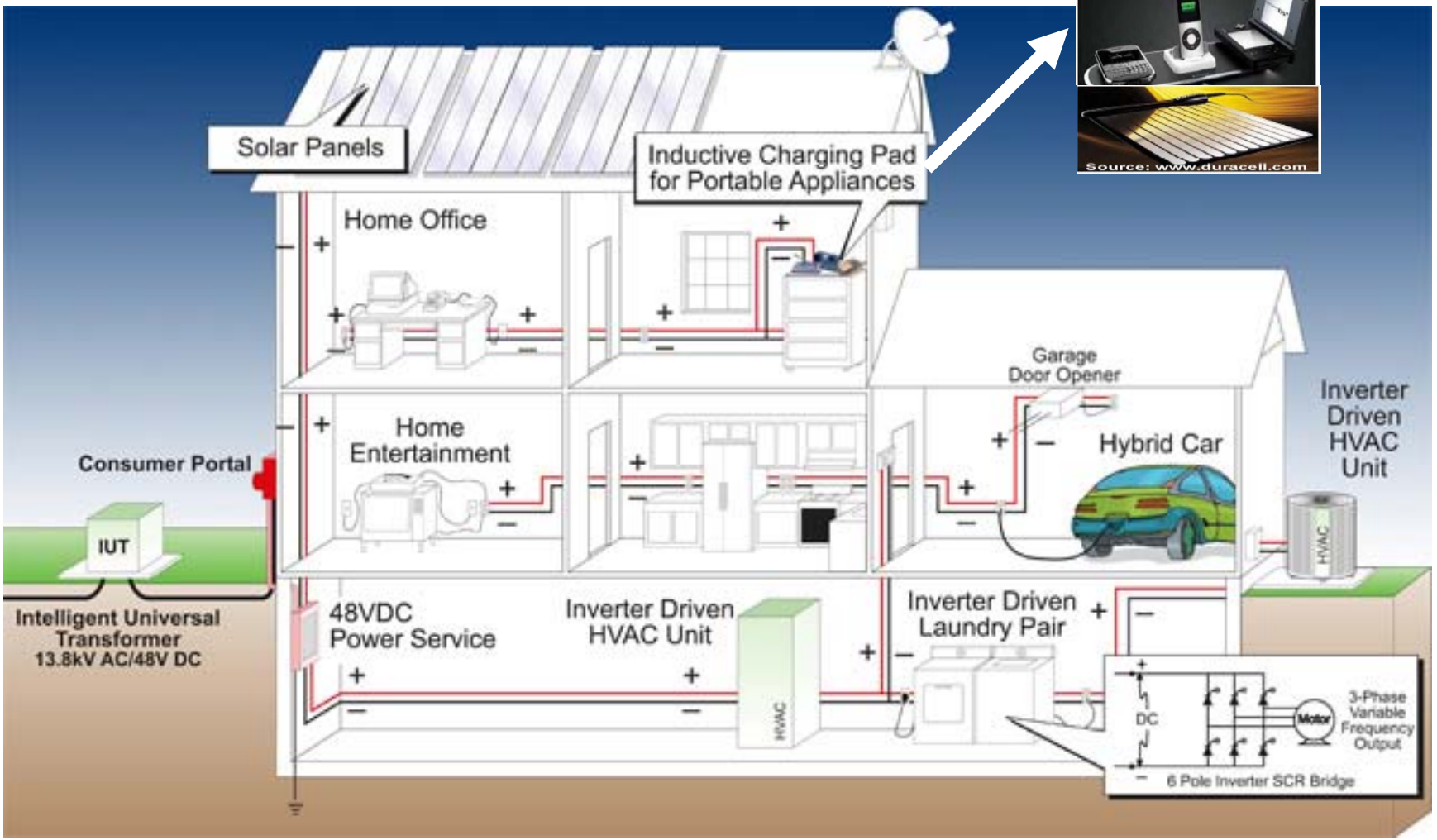
Easier Integration Of Renewables



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

Imagine…….



Together…Shaping the Future of Electricity