



GE Energy



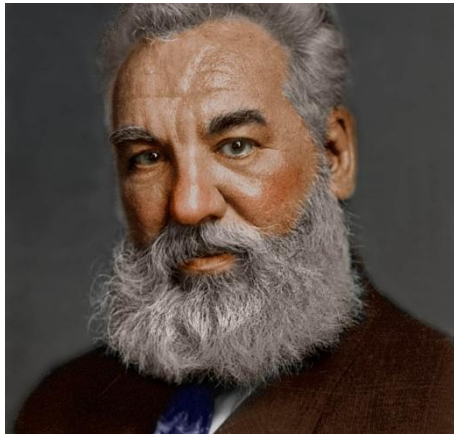
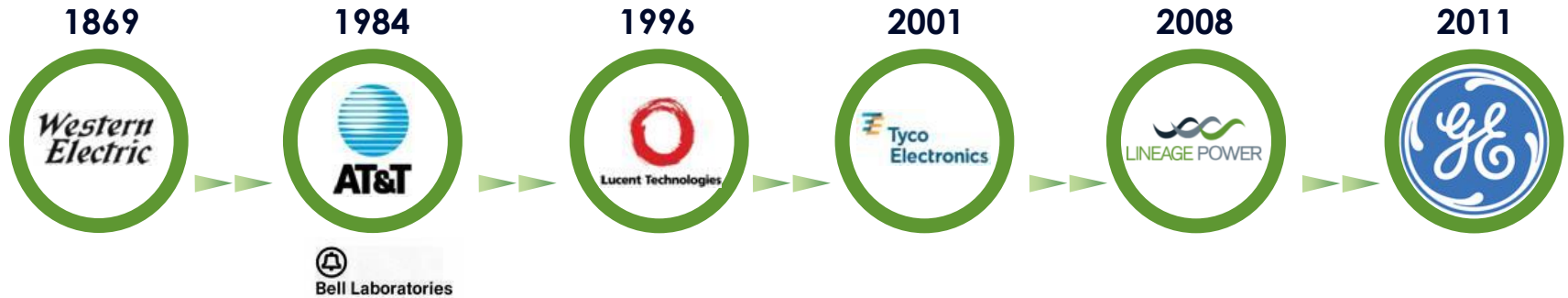
Information and Communication Technology Portfolio Review

Lineage Power, A GE Energy Company
Mark Johnson



- Introduction
- Project Objectives
- Background
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- Game Changing
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- Summary

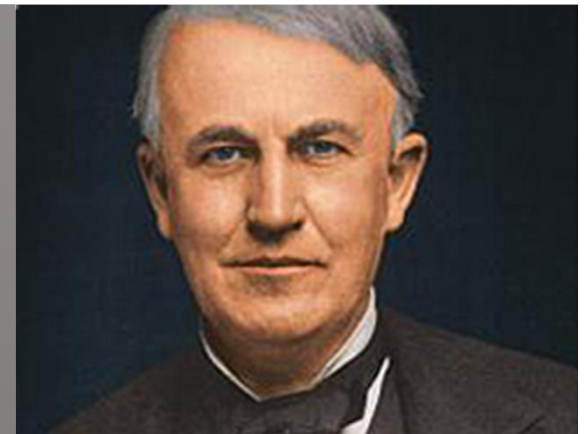
Uniting the Heritage of DC Power Innovation



Bell

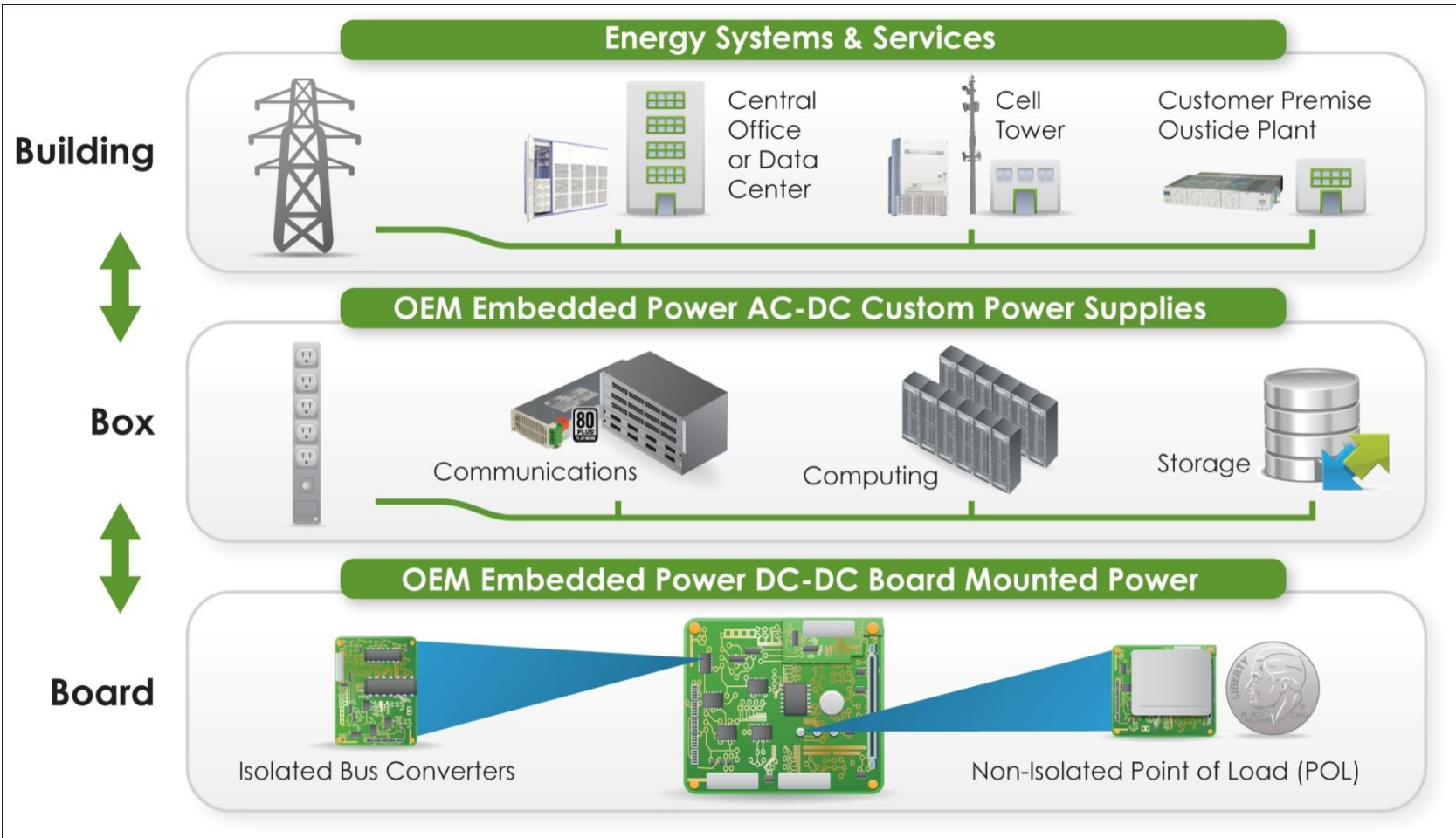
"I never perfected an invention that I did not think about in terms of the service it might give to others."

THOMAS ALVA EDISON, GE FOUNDER



Edison

End-to-End High Efficiency Power Conversion



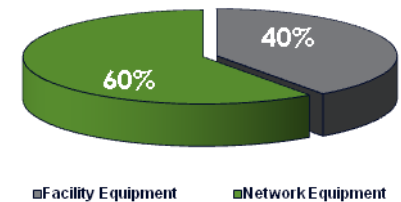
High Efficiency Wideband Three-Phase Rectifiers and Adaptive Rectifier Management for Telecom Central Office and Large Data Center Applications

- Lead: Lineage Power
- Principal Investigator: Mark Johnson, Energy Systems R&D Director
- Partner: Verizon
 - Provided data and advice in preparing the proposal
 - Offered access to five CO sites for experiments
 - No cost-sharing or access to grant funds
- Project Duration: 11/26/2009 -- 3/31/2012
- Project Type: R&D plus field experience

- Creation of next generation true three-phase high power rectifiers providing greater than 96% efficiency. Current generation products are 91% and legacy products are 88% efficient.
- Creation of a software technology to optimize overall plant efficiency yielding a point or two improvement.
- Characterization of typical central office energy consumption before and after installation of the above products.
- Share results at Intelec 2012

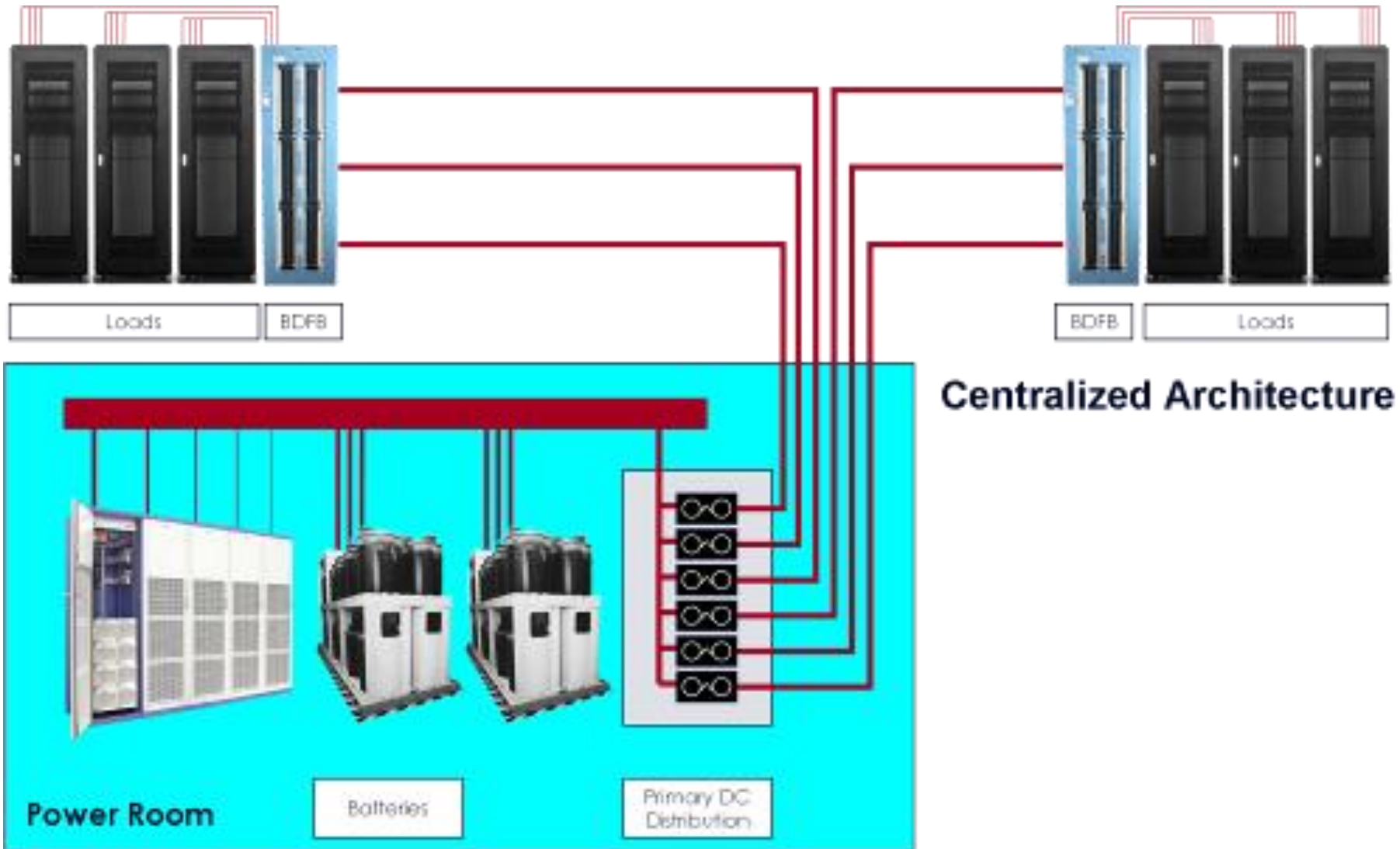
Project Background

- Worldwide, Total Energy usage in the Telecom industry is estimated at 160 Billion kWh
 - North American portion of this ~ 30% or 48 Billion kWh
- \$4.8B is spent by the NA Telecom Industry on Power annually** (Average utility cost of \$0.10/kWh)
- Telco estimates of power usage show that approximately 60% of the power is used by the Network Equipment itself
 - \$2.9B is spent in powering Network Equipment
 - If the average CO Power Plant efficiency is 82%, then 18% of \$2.9B or ~\$500M could be subject to efficiency improvement action plans.
 - Including the associated HVAC savings for improved efficiency:



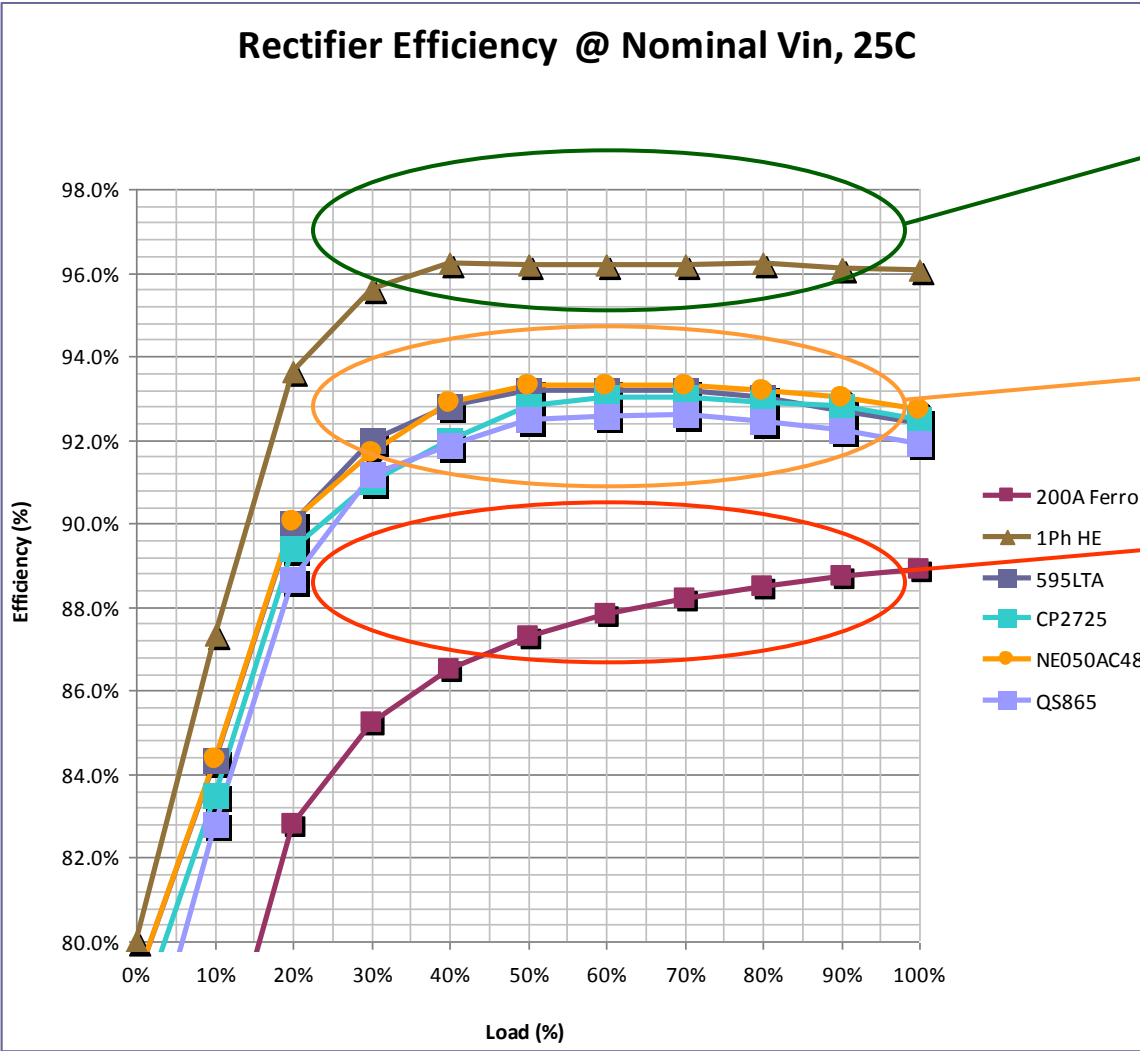
Every 1% improvement in overall DC Power Plant efficiency could save \$42M industry wide in North America

Typical Central Office Power Architecture



Rectifier Efficiency

Rectifier Efficiency @ Nominal Vin, 25C



- **New Generation “High Efficiency” SMR**

- **95-96% Efficient**

- **2nd Generation SMR**

- **91-93% Efficient**

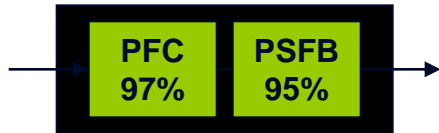
- **Typical 200A Ferro Resonant**

- **84-89% Efficient**

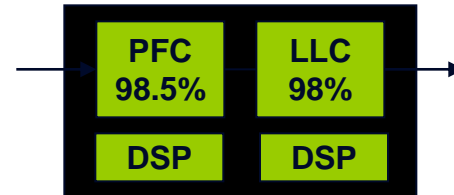
$$\text{Efficiency} = \frac{\text{Output Power}}{\text{Input Power}}$$

Approach To Improving Rectifier Efficiency

Traditional Design – 92%



High Efficiency Design – 96+%



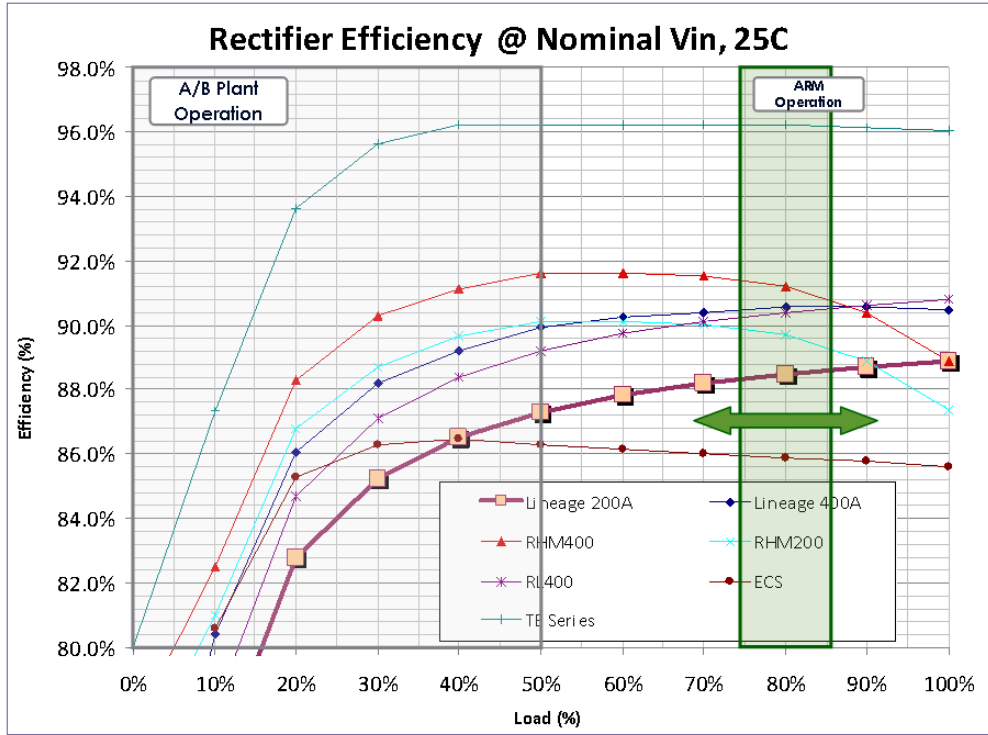
Traditional Design



High Efficiency Design

- PFC Optimization to get the right balance of conduction and switching losses
 - SiC diodes minimize switching losses
 - Better magnetic materials to reduce core losses
- New circuit topologies
 - 3 Level Bridgeless Boost PFC eliminates AC commutating diode losses
 - LLC resonant topology for DC/DC allows ZVS across the entire operating Load Range
- DSP control to flatten the efficiency curve between 20% to 100% loads
 - Adjust boost voltage, to operate LLC at peak efficiency
 - Adjust boost switching frequency to minimize switching losses
- Better Packaging to minimize parasitic losses and efficient cooling
 - Minimizes I²R Losses
 - Minimizes switching losses with tight switching Loops
 - Optimized airflow to minimize conduction losses in silicon devices

Approach To Achieve Plant Efficiency



Small A/B Plant Example

- 600A Load Capacity, 300A Actual
- 3 x 200A Ferro Rectifiers per Plant

Conventional - 84% Efficiency

- 150A per plant
- 6 rectifiers running at 50A each



ARM - 88% Efficiency

- 150A per plant
- 4 rectifiers on standby
- 2 rectifiers running at 150A each



Adaptive Rectifier Management (ARM)

- Drive operation of rectifiers to most efficient region
- Place least efficient rectifiers on standby
- Rectifiers in Standby instantly respond to load changes

Expected Results

Verizon CO Site	Original Equipment	Plant Efficiency	Planned Upgrade	Upgraded Plant Efficiency
Irving, TX	5 x 200A Ferro	88%	5 TE SMR + ARM	97%
Arlington, VA	6 x 400A Ferro	90%	12 TE SMR + ARM	97%
Santa Monica, CA	24 x 595A SMR	91%	ARM	92%
Roselle, NJ	8 x 595B SMR	91%	4 TE SMR + ARM	93%
Buffalo, NY	6 x 595B SMR	91%	6 TE SMR + ARM	96%

Item	Plan / Actual
595LTB S2 (208VAC, 220A)	December 2010
595LTA S2 (480VAC, 220A)	June 2011
ARM Controller Firmware	June 2011
Data Collection (Before)	August 2011
Site Upgrades	December 2011
Data Collection (After)	June 2012
Intelec Paper	November 2012

Game Changing - Retrofits

Retrofit Strategy

- match customer touch-points
- minimize installation cost

Before: 84% Ferros

After: 96% SMR

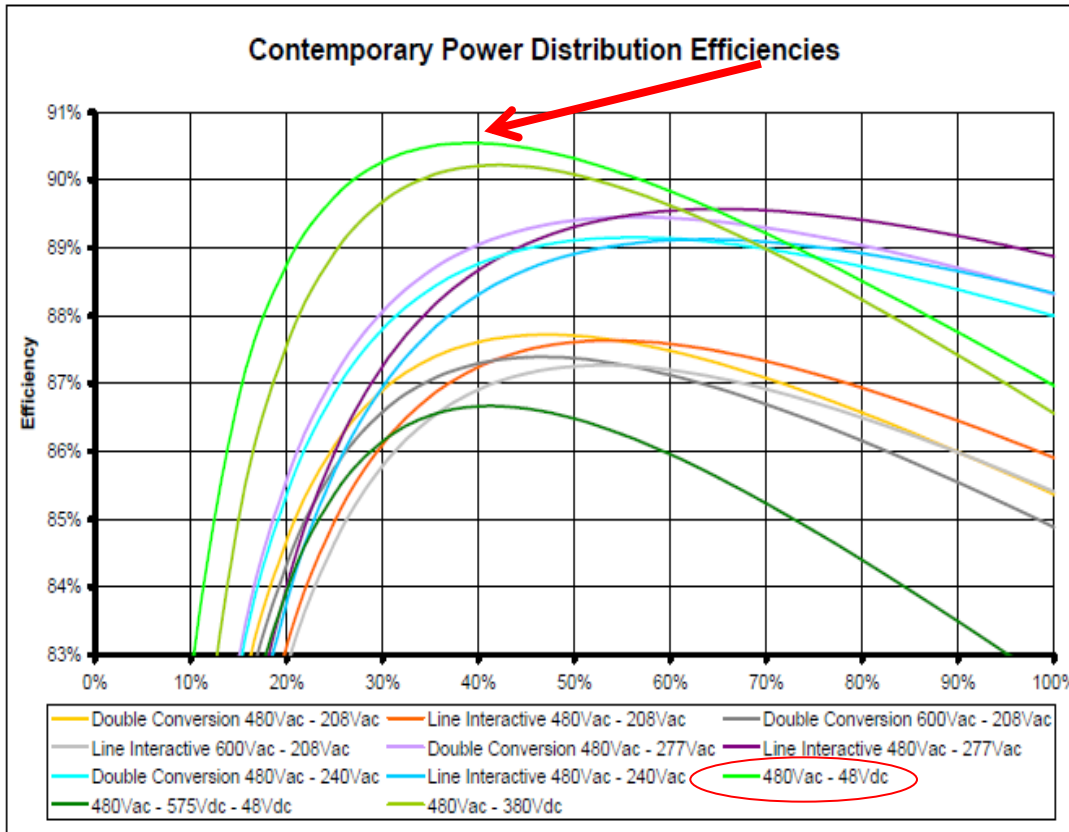


2 hours / unit vs 5 day plant replacement



Customer performs plug-in upgrades

Game Changing - Datacenter Power



- Most critical loads operate with less than 50% load on the power equipment
- One architecture is superior over the range that matters
- That architecture is the standard 48Vdc telecom distribution applied to a data center



Energy Savings – Typical CO

- Ferro (200A)
 - 480V 3 phase input
 - 6,000A Capacity Plant
 - 5,000A load
 - 88.5% efficient @ 83% utilization
 - 293,792W input power
 - 260,000W to load
 - 33,792W loss
 - 296,016KWh/yr heat output
- **SMR (595LTATE – 220A)**
 - 480V 3 phase input
 - 6,000A Capacity Plant
 - 5,000A load
 - **95.9% efficient @ 83% utilization**
 - **271,116W input power**
 - 260,000W to load
 - **11,116W loss**
 - **97,374KWh / yr heat output**

• **Saves 397,284KWh/year
(\$41,992.90 @ 10.57¢ per kWh)**

• **14 month payback period ***

**115,184 W Reactive Power
burden on utility**

**17,887 W Reactive Power
burden on utility**

•Based on ASP of Replacement Rectifiers and RPS cabinet s, installed – installation costs may vary
•Included 25% rectifier recovery credit and repair cost avoidance

Estimates of Energy Savings

- 23,000 Central Offices in the US
- Estimated 40,000 Ferro and 120,000 SM rectifiers in the field
- Realistic replacement rate: 300 Ferro and 1000 SMR per year
- Annual Energy Savings: 5,428,900 kWh
- Annual CO2 Reduction: 4,000 Metric Tons
- Rate will have to accelerate as equipment ages



Jobs/Employment

Direct Jobs Impact of the Grant

- Retain 3 highly skilled rectifier engineers
- Retain 1 highly skilled controller software engineer
- Hired 2 highly skilled software engineers
- Hired 2 electronics technicians
- Hired 1 project manager
- 56 hours of field engineering work
- 580 hours of field installation work

- => 500 R&D staff hours per week

National Jobs Impact of Full Deployment

23,000 Central Offices X 3 staff days/office = 275 staff years of labor

- 208VAC 220A rectifier is complete
- 480VAC 220A rectifier is at final prototype, Production due in June
- ARM Controller firmware drafted, due in June
- Data collection behind schedule
 - Irving, TX complete
 - Arlington, VA and Santa Monica, CA due May 9th
 - Roselle, NJ and Buffalo, NY due June 3rd

What's left?

- Finish 480VAC 220A Rectifier
- Finish Adaptive Rectifier Management feature
- Finish installation of data collection equipment at Verizon Cos
- Collect six months of energy consumption data
- Upgrade the five Verizon CO sites
- Collect six months of energy consumption data
- Prepare study for publication at 2012 Intelec

Post ITP Sponsorship – Commercialization

- Customer interest is keen!
- Energy Savings Calculator
- Strong sales force, excellent customer relationships
- Large embedded base – retrofit strategy
- Exploring greater penetration into data center market
 - Green Grid study on power architecture
 - 48V CO is most efficient and most reliable
- Designs applicable to alternative data center architectures
 - 480VAC power to the rack
 - Integrated short duration holdover in the rack
 - 48VDC backbone power in the rack

Value Proposition for End User

Category	Savings	Impact
Medium plant Ferro to SMR	\$6,302 @ 10.57¢ per kWh 9 month ROI	50% less energy loss and cooling requirement
Large plant Ferro to SMR	\$91,812 @ 10.57¢ per kWh 12 month ROI	50% less energy loss and cooling requirement
Active Rectifier Management	\$5,000 - \$10,000 per plant per year	Up to 90% recapture in low load conditions
Investment Protection	\$100,000 per site in cabling and installation	No forklift upgrades

**We leave no power system behind...
backwards compatibility avoids forklift upgrades**

Value Proposition – Energy Savings Calculator

Cost of Power™ Calculator

Site: **1234 Main Street**
Anytown, USA

DC Load: **5,000 Amps**
DC Voltage: **52.00 Volts**



Key:
Drop Down choice:
User Entry:

Legacy Plant

Rectifier Inventory:

Select:		Capacity	Qty	Capacity	Efficiency
LP 200A	Ferro	200 A	30	6,000 Amps	88.5%
RL400	Ferro	400 A	0		
595LTA	SMR	220 A	0		
RL400	Ferro	400 A	0		
RL400	Ferro	400 A	0		

Total Rectifier Capacity: 6,000 Amps

Calculations:

Recharge Factor: 1.20
Utilization: 83.3% (DC Load / Total Rectifier Capacity)
Power Plant Input Pwr.: 2,573,616 KWhr
HVAC Input Pwr.: 296,016 KWhr
Total Utility: 2,869,632 KWhr \$272,041.08

Building Parameters

State: **NY** EIA Estimate: 15.47 c / KWhr
Use Utility Rate: **9.48** cents / KWhr
Bldg HVAC: **Low Efficiency (5 + Yr Old)**
Climatic Adjustment: **100%**

Calculations:

HVAC Efficiency: 1.0 W per Watt Cooled
HVAC COP: 1.0 HVAC SEER: 3.4

Legacy Repair and maintenance costs

Failure Rate: **2.0%** per year
Avg Mat'l cost: **\$1,000** each
Avg Repair (labor): **\$200** each
Avg Annual Cost: \$720 (0.60 failures per yr)

Upgraded Plant

Existing Rectifiers - New Quantity:

		Capacity	Qty	Capacity	Efficiency
LP 200A	Ferro	200 A	0		
RL400	Ferro	400 A	0		
595LTA	SMR	220 A	0		
RL400	Ferro	400 A	0		
RL400	Ferro	400 A	0		

Additional SMR Rectifiers, Select:

595LTA-TE		220 A	27	5,940 Amps	95.9%
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Total Rectifier Capacity: 5,940 Amps

Calculations:

Recharge Factor: 1.19
Utilization: 84.2% (DC Load/Total Rectifier Capacity)
Power Plant Input Pwr.: 2,374,974 KWhr
HVAC Input Pwr.: 97,374 KWhr
Total Utility: 2,472,348 KWhr \$234,378.58

Upgrade System:

	Qty	ASP	Ext Cost
<input checked="" type="checkbox"/> Cabinet	7	\$5,000.00	\$35,000.00
<input checked="" type="checkbox"/> Controller	1	\$1,050.00	\$1,050.00
Rectifiers	27	\$3,300.00	\$89,100.00
<input checked="" type="checkbox"/> Adapters	0	\$0.00	\$0.00
<input checked="" type="checkbox"/> Shelves	27	\$0.00	\$0.00

Total Hardware Cost

\$125,150.00

Installation: **4.8%** (of Hardware)

\$5,944.63

Customer Engineering: **0.0%** (of Hardware)

\$0.00

Total

\$131,094.63

Expected Service Life: 25yrs

Annual Utility Savings: 397,284 KWhr \$37,662.51

Simple Payback Period: 1.3 Yrs (15 Months)

Annual CO₂ Reduction: 286.0 Metric Tons

(CO₂ Based on Utility conversion rate of: 0.00072 Tons / KWhr.)



- Good progress on product developments
- Difficulty collecting field data
- Compelling business case for older central offices
- Excellent potential for data centers
- DOE support is much appreciated!



imagination at work