LVDC-Redefining Electricity
First International Conference on Low Voltage Direct Current

New Delhi, India,
26 & 27 October 2015
380VDC Eco System: Current Status of Development

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Network Power

Optimizing and Deploying Critical Infrastructure for Today’s Mobile, Always-On World

WHAT WE DELIVER

Hardware, software and services that are intelligent, resilient and rapidly deployable for:

- Data Centers
- Communication Networks
- Healthcare Facilities
- Industrial Facilities

OUR BRANDS INCLUDE

ASCO®  Avocent®  Chloride®  Liebert®
NetSure™  Trellis™
**Network Power**

2014 At-A-Glance

**Sales**

$5.1B

**Employees**

~24,000

**Operating Profit > 12 Percent**

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**Sales by Product**

- DC Infrastructure Management & IT Solutions: 14%
- Thermal Management: 14%
- Services & Solutions: 21%
- Power: 51%

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**Customers Include**

AT&T, Bloomberg, China Mobile, China Telecom, Cisco, Digital Realty Trust, Equinix, IBM, NBN Co., Oracle, Reliance Industries Limited, Verizon, Walmart

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**Sales by Geography**

- United States and Canada: 42%
- Europe: 19%
- Asia: 29%
- Middle East/Africa: 6%
- Latin America: 4%

*Includes part of Embedded and Connectivity 2014 sales*
Network Power Global Presence

Network Power - Representatives and Distributors...

...in Every Major Country Around the World

North America

US & Canada
- Service Centers: 80+
- Service Field Engineers: 965+
- Technical Support/Response: 145+

Europe, Middle East & Africa
- Service Centers: 60+
- Service Field Engineers: 685+
- Technical Support/Response: 90+

Caribbean & Latin America
- Service Centers: 15+
- Service Field Engineers: 535+
- Technical Support/Response: 100+

Asia Pacific
- Service Centers: 95+
- Service Field Engineers: 945+
- Technical Support/Response: 75+

NORTH AMERICA
- Canada, United States

EUROPE, MIDDLE EAST & AFRICA
- Algeria, Austria, Azerbaijan, Bahrain, Benin, Croatia, Czech Rep., Denmark, France, Germany, Greece, Hungary, Ireland, Italy, Lithuania, Kenya, Kazakhstan, Nigeria, Norway, Oman, Poland, Portugal, Qatar, Romania, Russia, Saudi Arabia, Senegal, Slovakia, Slovenia, South Africa, Spain, Sweden, Switzerland, Turkey, United Arab Emirates, United Kingdom, Uzbekistan

ASIA PACIFIC
- Australia, Bangladesh, Bhutan, Brunei, Cambodia, China, Hong Kong, India, Indonesia, Japan, Korea, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, Papua New Guinea, Philippines, Singapore, Sri Lanka, Thailand, Taiwan, Vietnam

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DC Power Penetration

Semi-conductors began to evolve in the 1940s and 1950s and have become the predominant means of using power, and about 80 percent of power used in commercial buildings must go through some form of power electronics so it can be converted to DC," quote from studies conducted by the Center of Power Electronics Systems at Virginia Tech.

DISTRIBUTED RESOURCES

RISE OF DIGITAL ECONOMY

Demand for "digital quality" power is growing rapidly
Requires much higher reliability and quality
New devices have different characteristics
Increasing rack power density

>40kW

< 2 kW

Increasing drive for efficiency

**AC Power**
- New High Efficiency Topologies
- Traditional AC UPS Powered

**DC Power**
- Future Higher Voltage Topologies
- New 48V DC Topologies
- Telecom 48V DC Configurations

Increasing component integration on site

- Pre-engineered Scalable Building Blocks
- Containerized

Forces Re-evaluation of All Available Topologies

View of Data Center Trends – 2005 Infrastructure Prospective
Increasing rack power density

Increasing drive for efficiency

AC Power
- New High Efficiency Topologies
- Traditional AC UPS Powered

DC Power
- Future Higher Voltage Topologies
- New 48V DC Topologies
- Telecom 48V DC Configurations

Increasing component integration on site

- Pre-engineered Scalable Building Blocks
- Containerized
- Server Rack
- Blade Center
- Single Server

Forces Re-evaluation of All Available Topologies

Data Center Trends Evolution - 2010
Megatrends in Data Center Power Distribution Evolution

- Multiple approaches to infrastructure build-out
- Single solution does not fit all – high level of customization
- Less intelligence at infrastructure component level – centralized telemetry and control
- Local generation content
- Ease of transition to new infrastructure models
- Simplify compute gear (global voltage)

**SDDC** - Software Defined Data Center

**SDN** – Software Defined network

**LVDC (380VDC) Distribution**
Is the Best Choice to Meet the Needs and Demands of Modern Data Centers

**OBJECTIVE:**
- Decrease utility power consumption – peak shaving and over time
- Address all loads (lighting, cooling, etc.), not only compute loads
- Maintain high availability
- Dynamically match supply to demand
- Best system utilization – rightsizing, no stranded power, simplified distribution
- Scalability
- Significantly lower initial cost and TCO
400V DC Power Markets & Benefits

400V DC power has applications in three different markets, with different primary benefits driving adoption in each:

- **Data Centers**
  - Simple Architecture / Few Conversions

- **Telecom**
  - Cable Savings

- **Commercial Building Microgrids**
  - Easy Integration of Energy Sources

**Other Benefits:**
- No Phase / Voltage Balancing
- Increased Power Chain Efficiency
- Smaller Footprint per kW
- Reduced Distribution Losses
Energy Path to Load Simplified with DC Distribution

Traditional AC UPS

DC UPS

Simplified Architecture and Reduced Conversions with 400V DC Distribution vs. AC
Drivers for 400V DC in Telecom Core

- Savings in Core site deployments due to 85% reduced current vs -48V DC
  - Reduced cabling
  - Lower installation costs
- Improved cable management
- “Future-proof”: ability to power both existing -48V loads and new 400V loads

Other Benefits:

- No Phase / Voltage Balancing
- Increased Power Chain Efficiency
- Smaller Footprint
- Reduced Distribution Losses

Lower Total Cost of Core Infrastructure vs. -48V
Copper Reduction Possibility

- **CapEx savings:** >80% on cable, lugs and installation labor for new build out sites with 400V loads
- **OpEx savings:** 5% decrease in cooling consumption due to cascade effects of reduced line losses throughout the power chain

### Cabling Weight Comparison

#### Model A (200kW centralized model)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>200kW Battery</td>
<td>25m</td>
<td>25m</td>
<td>20m</td>
</tr>
<tr>
<td>200kW DC UPS &amp; Primary Distribution</td>
<td>8 BDFB</td>
<td>8 BDFB</td>
<td></td>
</tr>
<tr>
<td>25kW BDGB</td>
<td>X 8 circuit</td>
<td>X 8 circuit</td>
<td>X 12 circuit</td>
</tr>
</tbody>
</table>

#### Comparison of Cable Weight

<table>
<thead>
<tr>
<th>Load</th>
<th>System Current (A)</th>
<th>Cable Weight (kg over 25m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>48V Load</td>
<td>3700 A</td>
<td>2700 kg</td>
</tr>
<tr>
<td>400V Load</td>
<td>530 A</td>
<td>200 kg</td>
</tr>
</tbody>
</table>

#### Tabular Data

<table>
<thead>
<tr>
<th>Load</th>
<th>Batt Cells (2V/ea)</th>
<th>Float Voltage (2.25V/cell)</th>
<th>System Current (A)</th>
<th>Cable Weight (kg over 25m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>48V Load</td>
<td>24</td>
<td>54 V</td>
<td>3700 A</td>
<td>2700 kg</td>
</tr>
<tr>
<td>400V Load</td>
<td>168</td>
<td>378 V</td>
<td>530 A</td>
<td>200 kg</td>
</tr>
</tbody>
</table>

#### % Change

- 48V Load: (85)%
- 400V Load: (93)%

-48VDC total = 5.1 ton, 380VDC total = 0.3 ton (341kg)

-4.8 ton (93%) of copper would be reduced

Cable to transport 200kW 245 ft
Canadian Telecom Example

• **Background:**
  - -48V DC equipment loads were a significant distance from the power room (400 feet)
  - -48V DC required expensive copper cabling and created cable management issues

• **Solution:**
  - 400V DC power system installed in power room to distribute 400V DC on long cable run
  - 400V/48V DC-DC converter installed in equipment room, near -48V loads

• **Results:**
  - 40% cost savings
  - Results published in INTELEC 2014 paper: “Case Study of 400V DC Power with 400V/-48VDC Conversion”
Telecom Facility Transformation Vision

Present

48VDC

Utility
Gen

AC UPS
DC UPS

Facility AC loads
AC compute loads
Telco and dc compute loads

Interim

400VDC

Utility
Gen

AC UPS
DC UPS

Facility AC loads
AC compute Legacy loads
DC compute And telco loads

Ultimate

400VDC

Utility
Gen

DC Energy Station
Green Generator

Facility DC loads
DC compute And telco loads

Many transition paths

EN 300 132-3-1 (260-400V) at input of IT load
Transitioning from -48V to 400V DC

Long term:
All loads powered by 400V DC
Expand power capacity as needed

Row Level

Rack Level
Zero Net Energy Buildings (ZEB)

DC Microgrid with Renewable & Alternate Distributed Generation

DC Microgrid may include:

- Various AC and DC loads: fixed & plug and play loads
- Dispatchable generation: fuel cell or bio-fuel turbine.
- Non-dispatchable sources: solar PV and wind turbines.
- Energy storage, such as ultra-capacitors or batteries.
- Common Distribution – Collector Bus
- Management & Demand Response (DR) capability
- Ride-thru & Off-grid operation capability (islandable)
Globally Recognized Benefits of 400V DC Distribution

- Single voltage (400VDC) global standards – fewer OEM equipment variations – potential equipment cost reduction
- Simplicity, scalability, ease of deployment
- High reliability – elimination of series conversion steps
- Power quality maintained (vs AC eco-mode)
- No need for phase balancing
- Elimination of harmonics impact
- Lower TCO
- Migration paths identified
400V DC Distribution Is Well Suited for Mission Critical Spaces

Vs AC UPS – Traditional Data Center

• Minimizes power chain conversions
• Easy integration of batteries on DC bus
• No harmonics, phase balancing
• Modular -> easy maintenance and scalability

Vs - 48VDC - Traditional Telco

• Higher voltage $\rightarrow$ significantly less distribution vs -48V DC
• More flexible, plug-n-play distribution options

400V DC – Combines Many of the Benefits of -48V DC and AC

Minimizes power chain conversions
Easy integration of batteries on DC bus
No harmonics, phase balancing
Modular -> easy maintenance and scalability

Higher voltage $\rightarrow$ significantly less distribution vs -48V DC
More flexible, plug-n-play distribution options
Many Hurdles to Adopting 400V DC Have Been Overcome

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Current State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global voltage selection and adoption</td>
<td>✓ 380 VDC selected globally</td>
</tr>
<tr>
<td>Applicable standards for 400V DC</td>
<td>Many International standards in place. Need to develop best practices and training.</td>
</tr>
<tr>
<td>Availability of 400V DC components (plugs, breakers, power strips)</td>
<td>✓ 400V DC components have been commercially available for several years</td>
</tr>
<tr>
<td>Availability of 400V DC loads (servers, storage, switches, etc)</td>
<td>✓ Some 400V DC loads are available. More are in development.</td>
</tr>
<tr>
<td>Operational changes in Telecom vs. - 48V</td>
<td>✓ Hybrid approach using 400/48V conversion maintains -48V at the rack 400V DC loads will require operational changes, but are feasible (plugs instead of lugs). Migration path identified.</td>
</tr>
<tr>
<td>Safety concerns</td>
<td>✓ HRMG system design mitigates arc and shock potential</td>
</tr>
</tbody>
</table>
Agency Status / Standards

- 400V system standards currently released or under development through international efforts
  - UL (several products listed today) – cover all distribution system components
  - ETSI EN 300 132-3-0 – power interface standard – RELEASED
  - ETSI EN 301605 – earthing and bonding for 400VDC systems - RELEASED
  - ITU – (ITU-T I.1200) – adopted ETSI voltage levels - RELEASED
  - ATIS- 0600315.01.2015 – voltage levels standard - RELEASED
  - SCTE – committee started
  - NEC – Current edition applies to both AC and DC: Wiring, protection, safety
    Continuous upgrades on 3 year cycle
  - EMerge Alliance - Focus on site and system interfaces – RELEASED
  - YD/T 2378-2011 (China Standard) - RELEASED
  - Planned update for 336V (380VDC) mid to late 2015
  - NEMA / EPRI – work in progress

- Standards also needed for and driven by renewable resource deployments

Standardization Work Closely Harmonized to Agree on Aligned Global Standards
ETSI EN 301 605 (Grounding and Bonding)- Summary

• Both system earthing arrangement comply with relevant safety requirements

• IF the continuity of operation is placed in the forefront THEN the symmetrical IT system ±200 Vdc with earthed high-ohmic mid-point is the first choice. In cases where an IT system is used for reasons of continuity of supply, automatic disconnection is not usually required on the occurrence of a first fault (single fault) to an exposed-conductive-part or to earth. This is valid on condition that an Insulation Monitoring Device (IMD) indicates the first fault by an audible and/or visual signal which shall continue as long as the fault persists.

• IF similar system earthing arrangement as for today’s -48 Vdc system is requested THEN the TN-S system +400 Vdc may be chosen.

Source - Ericsson
400V Eco-system Availability for Selected Major System Components

<table>
<thead>
<tr>
<th>DC Power System</th>
<th>DC Breaker</th>
<th>Bus way</th>
<th>Rack PDU</th>
<th>Connector</th>
<th>Rack-mount Power Supply</th>
<th>Power Components</th>
<th>ICT Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emerson</td>
<td>ABB</td>
<td>Starline PDL</td>
<td>ServerTech</td>
<td>Anderson</td>
<td>Artesyn</td>
<td>VICOR</td>
<td>NEI – Some models available</td>
</tr>
<tr>
<td>ABB</td>
<td>Carling</td>
<td>PDI Eaton</td>
<td>API Tech</td>
<td>Hubbel</td>
<td>Delta</td>
<td></td>
<td>HP – major platforms available</td>
</tr>
<tr>
<td>Delta/Eltek</td>
<td>Schneider</td>
<td></td>
<td>Delta</td>
<td>Rong Feng / Delta</td>
<td>AcBel</td>
<td></td>
<td>IBM* – some X and Z series available today</td>
</tr>
<tr>
<td>China vendors</td>
<td>Nader</td>
<td></td>
<td>Fujitsu Comp.</td>
<td>Fujitsu Comp</td>
<td>Many others</td>
<td></td>
<td>Lenovo – Flex chassis</td>
</tr>
<tr>
<td>Japanese vendors</td>
<td>Siemens</td>
<td></td>
<td>Echola</td>
<td>Bachmann</td>
<td></td>
<td></td>
<td>Cisco – UCS platform</td>
</tr>
<tr>
<td>GE</td>
<td>Eaton</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Juniper* – products in final evaluation</td>
</tr>
</tbody>
</table>

New Products Introductions in Most Categories Are Accelerating
DC UPS Constructions Principles for Safe Equipment Design
120kW Example

- Plug-in components
- Ability to service major elements without system shutdown
- Shielding and protective access
- Compartmentalize serviceable components
Connectors and Busway for DC Powered IT Equipment

APP Safety-Grid connector
- Approvals
  - UL 1977 Recognized & UL 817 Listed
  - IEC 61984 Certified
  - CCC Approved

Universal Starline Busway

<table>
<thead>
<tr>
<th>ac CONFIGURATION</th>
<th>dc CONFIGURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="ac Configuration Diagram" /></td>
<td><img src="image2" alt="dc Configuration Diagram" /></td>
</tr>
</tbody>
</table>

![Universal Starline Busway Image](image3)

Fujitsu Connector

Rong Feng Connector

Copyright 2014

[Steelorca Logo]

[IEC Logo]
Rack Distribution – Power Strips

- Similar construction to AC strips
- Loads can be hot plugged in or disconnected
400V DC Server Availability

• **HP**
  HP now offers 400V DC input in their common slot power supply for rack mount devices: ProLiant (DL, ML, SL), Storage, etc; support for c7000 blade soon
  Next generation (G9) of products will also include 400V power supplies (500, 800, and 1200W) for 45+ Server, Storage and Switch products

• **IBM/Lenovo:**
  Some X and Z series available today; Flex blade center support; rack mount common slot power supplies in development?

• **Cisco:**
  UCS platform, Fabric Interconnects and Nexus switches available (multiple power supplies available – 750W, 1100W, 3000, 2500W, several more in development)

• **Juniper:** Support for EX and QFX series top of rack switches

• **NEI:** catalog products available today, 1U and 2U servers

• **Supermicro:** 2 servers models available for trial

• **Huawei** – claims most platforms can support 400VDC

Common Slot Power Supplies by Most Vendors Are Wide Range, Supporting both HVDC and HVAC. All Vendors (Lenovo exception) Use APP connectors for Power Supplies, Rack PDU and Cords.
Emerson Network Power 400V DC
Early Deployments

- **Univ. California / EPRI**
  - 20kW
  - AC/DC Efficiency Study

- **France Telecom**
  - 2 x 50kW
  - Datacenter lab

- **Nextek**
  - 45kW
  - Building microgrid

- **Clustered Systems**
  - 105kW
  - High performance computing

- **European Carrier**
  - 30kW
  - Lab Evaluation

- **China Mobile**
  - 80kW
  - Lab evaluation

- **Server OEM**
  - 2 x 20kW
  - Lab

- **France Telecom**
  - 20kW
  - Telecom office

- **Server OEM**
  - 3 x 30kW
  - Lab

- **NTT-A**
  - 15kW
  - Server trial

- **US Carrier**
  - 30kW
  - Lab evaluation

**Timeline:**
- **2009**
  - China Mobile 80kW Lab evaluation
- **2010**
  - Server OEM 2 x 20kW Lab
- **2011**
  - France Telecom 20kW Telecom office
  - Server OEM 3 x 30kW Lab
- **2012**
  - NTT-A 15kW Server trial
- **2013**
  - US Carrier 30kW Lab evaluation
Emerson Higher Voltage DC Global Footprint

By September 2015 Emerson has delivered:
- 1100+ 240VDC systems
- 50+ 400VDC systems

Deployed across Asia, North America, Europe, and Africa in a wide range of applications:
- Telecom
- Data Centers
- Micro-grids
- High Performance Computing

Emerson 240VDC and 400VDC Platforms Have the Same Architecture and Utilize Similar or Same Assemblies
Emerson 240V DC Deployments in China

China Telecom Mega Center
Inner Mongolia

- Phase 1.1 finished 4 buildings, Emerson provided 65 sets of 240VDC systems.
- Single system with dual bus output
Emerson 240VDC Deployments in China

Nanjing Changle Central Office
- Distributed System application

Zhejiang Telecom Dongguan IDC
- Dual system Dual Bus

Guangdong Telecom Jinding IDC 2/2
- PDU Rack & PDU in Server Rack
Emerson 240V DC Deployments in China

Shanghai Baozhiyun IDC

- 80 systems of 240Vdc
- 240kW/system
- AC+240VDC dual supply
Emerson 240V DC Deployments in China

Tencent Modular IDC

- 12 server racks
- Power of each rack: 8kW
- Backup time: 10 min
- Space area: 3600mm (W) * 5300mm (L)
Emerson 240V DC Deployments in China

Baidu Yangquan IDC

**Phase One:** 7 systems of 360kW 240VDC

**Phase Two:** 63 Systems of 210kW 240VDC
Rectifier Cabinet and separate Battery Charger
Emerson 400V DC Global Footprint

400VDC France Telecom

ENERGY PREMISES

SERVER ROOM

FT datacenter Velizy, Emerson power system 400 VDC 50kW capacity with 30 min lead-acid, 1+1 redundant
- 3 to 8% lower losses vs. UPS at load 30-40 %
- 1,5% lower losses in distribution (less current in 400VDC vs. 230VAC and no harmonic losses)
- 3 to 5,5 % lower losses in the server
- 2 to 3% lower losses in cooling
→ Total loss reduction 10 to 18%

IBM and HP servers
Emerson 400V DC Global Footprint

Bachmann (Germany) 400V DC
Datacenter/Microgrid

Solar panels on roof

400V DC Data Center

AC servers

400VDC inverters

400VDC servers

Emerson 400VDC systems
Emerson 400V DC Global Footprint

400VDC+12VDC Solution for China Mobile - Harbin
Emerson in partnership with RSC installed 2 sites:

- **Saint Petersburg Polytechnic University (SPbPU)**
  - Polytechnic RSC PetaStream - 1st in Russia by energy efficiency level with 2,401.4 Mflops/Watt
  - #8 in local Top50 supercomputers list for Russia/CIS
  - Feed from NetSure 9500 120kW Power system and using Vicor 400/12V DC/DC converters

- **Joint Supercomputing Center of Russian Academy of Sciences (JSCC RAS)**
  - RSC PetaStream - The first project on Intel® Xeon Phi™ 7120D in Russia and CIS
  - Feed from NetSure 4015 30kW Power system and using Vicor 400/12V DC/DC converters
Emerson 400VDC Global Footprint

Xiamen University Microgrid

- Utility
- Solar Panel (150kW)
- Distribution
- Monitor

AC/DC
DC/DC (MPPT)
Battery

380VDC BUS

380V/24V Indoor Light
Datacenter
EV Charger
Cooling
Home Appliance
Outdoor Lamp

- 150KW solar panel
- AC/400Vdc : 180kW
- 400Vdc MPPT : 180kW
- EV charger
DCC+G European Microgrid Project
Office Building, Fraunhofer Institute in Germany

- 90kW +/- 380V DC Power System w/ Solar MPPT
- Specs:
  - Dual bus (+380V, -380V)
  - 90kW=6x15kW rectifiers
  - 30kW=2x15kW solar MPPT
  - (2) ACU+ controllers
  - 24U enclosure

Verification sites:
1. Fraunhofer Institute – building microgrid
2. Bachmann – green data center
3. Phillips – lighting

- 3 year project; April 2012 – April 2015
- Total budget of 18M €
- ENP budget 1M €,
  - 0.5M € funding from Vinnova and ENIAC JU
- Emerson team: Marek Szpek, Johnny Olsson, Barbro Karvall
- 13 world-class partners from 5 countries
  - 5 industry partners
  - 5 SME partners
  - 3 research institutes
- 37 deliverables (reports app. 40 pages each)
- 32 tasks
NextEnergy Center – Detroit ...

380v DC Microgrid

- 380v DC Bus
- 30kW Rectifier
- 23,300sf of 24v DC Lighting
- Wireless Controls
- 16kW of PV Solar
Plug in POD Design Concept Benefits – Example Deployment at Steel Orca

Hot plug-in maintenance concept

- 2(N+1), 2N, N+1 UPS configurations
- Busway with 2 End Feeds (Redundant)
- Busway plug-in units are added as racks are added (live)
- Racks can be removed without system shutdown

- During routine maintenance personnel is never exposed to live parts:
  - Server level
  - Rack level
Live 400VDC Demo Room @ Steel Orca

Stultz 400VDC in Row Cooling

GVA 400VDC Lighting

Components Display
Summary

- **400V DC:**
  - Ready for next phase of advancement
    - All major stakeholders actively involved
    - Increasing global interest; goal for uniform global standards
  - Field trial sites and production sites deployed at accelerated rate
  - Major infrastructure and equipment suppliers are engaged
  - Similar, modular architecture to 48V as deployed today
    - Benefits in copper reduction: cost, weight, ease of installation
  - Requires paradigm shift to “think differently”

Base Feasibility Confirmed
Accelerated Adoption Rate