Reasons for using LVDC in Data Centers

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Agenda

• The old AC-DC war
• Why AC ?
• The changes
• Why using DC in Data Centers ?
• Why using LVDC in Data Centers ?
• Where energy is going to...
• 380 VDC – the key to efficiency
• Comparing efficiency
• 380 VDC saves money
The old AC-DC war

• Known as Edison (DC) versus Westinghouse (AC)

• AC won, but paradigm has changed
  • AC solved the 1888 problem, but DC technology has progressed
• If the we were designing the grid today, it would probably be DC
In the traditional power system
- Production is centralized; large production sites use rotating generators, which are typically AC
- Passive magnetic transformers help optimizing voltage level based on power and distance
- Load does not care (light bulbs, heating resistors)
The changes (1)

- New loads use a lot of electronics
  - 80% of electrical energy is handled by power electronics\(^1\)
  - IT is almost 100% electronics
  - Electronic loads are inherently DC
- Connecting DC loads to the AC grid costs energy and money
  - A significant amount of the energy is consumed during conversions before it reaches the “real” load

\(^1\) Center for Power Electronics, based on new equipment shipped; 40% of installed base
The changes (2)

- Production becomes decentralized
  - Local “green” production is typically DC
    - Photovoltaic is inherently DC
    - Windmills frequency is not stable enough to allow direct connection to AC grid

- Connecting local sources to the AC grid costs energy and money
  - Part of the green energy is lost in conversions before it reaches any “real” load
  - DC is converted to AC and then back to DC
Why using DC in data centers?

- Loads are mainly computers, i.e. DC loads
- Power supplies with DC input are simpler
  - No need for PF correction/harmonics compensation
  - Fewer components = higher reliability, lower losses
  - Fewer components also improves sustainability
- A 173-year experience\(^2\) has proven the reliability of DC in telecommunication centers
- Locally generated power can be used without conversion to AC and back to DC
- DC is easier and cheaper to store than AC

\(^2\) Since the first electrical Telegraph, in 1838
Why using LVDC in data centers?

• 48 VDC is great, but...
  – Lot of copper => high investment
  – Less suitable for auxiliary equipment (lighting, cooling...)

• Higher voltage = lower current (for a given power)
  – True at all frequencies => also for DC
  – Increases efficiency for a lower investment

• 380 V with grounded middle point (-/+ 190 V) is a good compromise
  – Provides similar safety as 250 VAC
  – Allows connection of auxiliary equipment
Where energy is going to...

- UPS 480V AC
- PDU 480V AC
- PSU 208V AC
- VR 12V
- Fans

Electr. loads

- Server
- Room cooling 80W – 200W
- UPS 18W
- PDU 48W
- PSU 48W
- Server fans 13W
- Server

Total 285W – 405W

Intel
380 VDC – the key to efficiency
## Comparing efficiency

<table>
<thead>
<tr>
<th>Configuration</th>
<th>UPS</th>
<th>PDU</th>
<th>PSU</th>
<th>VR+fan</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional AC</td>
<td>88%</td>
<td>93%</td>
<td>79%</td>
<td>75%</td>
<td>48%</td>
</tr>
<tr>
<td>High efficiency AC</td>
<td>94%</td>
<td>94%</td>
<td>89%</td>
<td>86%</td>
<td>68%</td>
</tr>
<tr>
<td>= high-efficiency components in UPS, PDU, PSU and VR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Best-in-class AC</td>
<td>98%</td>
<td>94%</td>
<td>89%</td>
<td>86%</td>
<td>71%</td>
</tr>
<tr>
<td>= high-efficiency + best-in-class UPS (line-interactive or delta conversion)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>400 VAC</td>
<td>98%</td>
<td>97%</td>
<td>89%</td>
<td>86%</td>
<td>74%</td>
</tr>
<tr>
<td>= 3-phase 400 V distribution, 1-phase 250 V without transformer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-48 VDC</td>
<td>93%</td>
<td>97%</td>
<td>93%</td>
<td>86%</td>
<td>72%</td>
</tr>
<tr>
<td>= fewer conversions, but low voltage, large current</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>380 VDC</td>
<td>97%</td>
<td>97%</td>
<td>93%</td>
<td>86%</td>
<td>76%</td>
</tr>
<tr>
<td>= fewer conversions, lower currents</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Comparing efficiency

Power Delivery Efficiency [%]

- 380V DC
- 48V DC
- Best-in-Class 400V AC
- Best-in-class AC
- High efficiency AC
- Baseline AC

~30% gain
380 VDC saves money

• Savings are cumulative
  – Higher efficiency = lower losses
  – Lower losses = less heat
  – Less heat = less cooling need
  – Less cooling = more savings

• In total, direct savings are
  – 7 to 30% on consumption$^1$
  – 15% on investment$^2$
  – 33% on floor space$^2$
  – 36% on lifetime cost$^3$

• ... and this is not just for Data Centers

$^1$ Intel, Intelec Paper, 2007  
$^2$ Intel, HP/EYP, Emerson, Whitepaper, 2009  
$^3$ Validus/GE Study, 2011
Green.ch-ABB Zurich-West
380Vdc Data Center

- ABB/Validus Power Distribution
  - In: 16KV AC
  - Out: 1MW @ 380Vdc
  - Battery Backup: 10 mins
  - Backup Generation
- 1,100m² of 3,300m² Vdc
- HP 2U, Blades & Storage Servers
- Demonstrated Benefits
  - 10% Better Energy Efficiency
  - 15% Lower Capital Cost
  - 25% Smaller Footprint
  - 20% Lower Installation Costs

Photos courtesy of ABB* and HP*
Thank You

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## IEC 23E WG 2 – as safe as 250Vac, safer than 415Vac

<table>
<thead>
<tr>
<th>Voltage to earth</th>
<th>Breaking times (s) AC</th>
<th>Breaking times (s) DC</th>
<th>Fault protection (IEC 60364-4-41)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Direct contact (IEC 60479)</td>
<td>Direct contact (IEC 60479)</td>
<td>TN</td>
</tr>
<tr>
<td></td>
<td>I∕un max= 30 mA</td>
<td>I∕un dc max= 100 mA</td>
<td>0,4</td>
</tr>
<tr>
<td>400V</td>
<td>560 Ω</td>
<td>560 Ω</td>
<td>0,4</td>
</tr>
<tr>
<td></td>
<td>714 mA Not possible</td>
<td>714 mA Not possible</td>
<td></td>
</tr>
<tr>
<td>300V</td>
<td>595 Ω</td>
<td>595 Ω</td>
<td>0,4</td>
</tr>
<tr>
<td></td>
<td>500 mA Limit. Not recommended</td>
<td>500 mA Limit. Not recommended</td>
<td></td>
</tr>
<tr>
<td>250V</td>
<td>620Ω</td>
<td>620Ω</td>
<td>0,4</td>
</tr>
<tr>
<td></td>
<td>400mA 150ms safety margin for ac is aprox. 1/4 (40 ms)</td>
<td>400mA 80ms Does not allow same safety margin as for ac</td>
<td></td>
</tr>
<tr>
<td>200V</td>
<td>640 Ω</td>
<td>640 Ω</td>
<td>5</td>
</tr>
<tr>
<td>(3 wires with Middle point grounded)</td>
<td>300mA 150ms Allows comparable safety margin as for ac (1/4)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
380Vdc: the New Standard

- ETSI 300132-3-1 v2.1.13 (1) (2011)
  - EMerge Alliance ➔ NEC 2013
    - 28% more efficient than 208VAC
    - 7% more efficient than 415VAC
    - 15% less up-front capital cost in volume
    - 33% less floor space
    - 36% lower lifetime cost
    - 200%-1000% more reliable
    - No Harmonics, As Safe or Safer
- Other Industries likely adopters
  - PV, Wind, Lighting, EV Charging, VFD Motors, Fuel Cells
  - Commercial Offices – EMerge DC building backbone

380Vdc Running in Real Data Centers

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1 Intel, Intelec Paper, 2007  
2 Intel, HP/EYP, Emerson, Whitepaper, 2009  
3 Validus/GE Study, 2010  
4 IEC 23E WG2 as safe as 250Vac, safer than 415Vac
Why 380Vdc just makes sense

The Keys to Efficiency
- Higher Voltage (independent of frequency)
- Fewer Conversions

The Key to Cost Effectiveness
- Volume Priced Parts (< 420Vdc)

380VDC: Highest voltage with volume components, fewest conversions