Percentage of power delivered to IT equipment

All values are shown as a fraction of the respective data center total power consumption. Average 0.49
Benchmarking energy end use

Electricity Flows in Data Centers

UPS = Uninterruptible Power Supply
PDU = Power Distribution Unit;
Overall power use in Data Centers

Courtesy of Michael Patterson, Intel Corporation
Data Center power conversions

Uninterruptible Power Supply (UPS)

Power Distribution Unit (PDU)

AC/DC Multi output Power Supply

PWM/PFC Switcher

Unregulated DC & Multi Output Regulated DC Voltages

Voltage Regulator Modules

5V
12V
3.3V
12V
12V
3.3V
3.3V

Internal Drive
External Drive
I/O
Memory Controller
μ Processor
SDRAM
Graphics Controller

In

Battery/Charger Rectifier

Inverter

Bypass

Server
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.

Power for cooling can equal or exceed the direct losses.
Prior research illustrated large losses in power conversion.

**Power Supplies in IT equipment**

- **Uninterruptible Power Supplies (UPS)**
  - Factory Measurements of UPS Efficiency (tested using linear loads)
  - Flywheel UPS
  - Double-Conversion UPS
  - Delta-Conversion UPS
UPS labeling

- Based upon proposed European Standard
- Possible use in Energy Star program
- Possible use in Utility incentive programs
- Possible use in Federal Procurement specs
Typical AC distribution today

480 Volt AC

AC/DC -> DC/AC

UPS

PDU

AC/DC -> DC/DC

PSU

Server

VRM

VRM

VRM

VRM

VRM

VRM

12 V

12 V

12 V

5 V

3.3 V

1.2 V

1.8 V

0.8 V

Loads using Legacy Voltages

Loads using Silicon Voltages
Distribution considerations

- Distributing higher voltage AC or DC to the load is more efficient
- Less copper at higher voltage – copper cost is very high
- Safety is key consideration
- Electricians are needed at higher voltages
- Disconnecting DC creates an arc
- UL rated equipment exists
- Equipment in use is rated to 600V. now.
Thomas Edison:

“My personal desire would be to prohibit entirely the use of alternating currents. They are as unnecessary as they are dangerous. I can therefore see no justification for the introduction of a system which has no element of permanency and every element of danger to life and property.”
Various DC architectures

Several options: 300V, 350V, 380V (48V)

550V DC

480V/400V AC

480V/400V AC

12V

PDU

PSU

PDU

PSU

VR

VR

Rack

Server

Rack

Server

Various DC architectures

Courtesy of Annabelle Pratt, Intel
380 V. DC Demonstration

- Side-by-side comparison of traditional AC system with new DC system
  - Facility level distribution
  - Rack level distribution
- Power measurements at conversion points
- Servers modified to accept 380 V. DC
- Artificial loads to more fully simulate data center
Facility-level 380 V. DC distribution

- 480 Volt AC

AC/DC
DC UPS or Rectifier

380V: 380 Volt AC

DC/DC

12 V
VRM

5 V
VRM

3.3 V
VRM

1.2 V
VRM

1.8 V
VRM

0.8 V
VRM

Loads using Legacy Voltages

Server

Loads using Silicon Voltages
Rack-level DC distribution

480 Volt AC

UPS → PDU → AC/DC → DC/DC → VRM → Load using Legacy Voltages

UPS → PDU → AC/DC → 380 VDC → VRM → Load using Silicon Voltages

Server
Measured Best in Class AC system loss compared to DC

7-7.3% measured improvement

2-5% measured improvement
Picture of demonstration set-up
- see video for more detail
Demonstration Highlights

- All equipment was commercially available and UL rated.
- Connectors at the IT equipment need to be standardized.
- Typical energy savings can be 20% or more.
- Reliability is expected to be improved - fewer points of failure.
- In the long term, first cost could be lower.
Most of the Center Can Operate on DC

- DC lighting was included
Most of the Center Can Operate on DC

- Lighting
- HVAC

On-Site Power Production (DG)
Implications could be even better for a typical data center

- Redundant UPS and server power supplies operate at reduced efficiency
- Cooling loads would be reduced.
- Both UPS systems used in the AC base case were “best in class” systems and performed better than benchmarked systems - efficiency gains compared to typical systems could be higher.
- Further optimization of conversion devices/voltages is possible
## Data Center Power Delivery

For a typical center energy savings could exceed 20%

<table>
<thead>
<tr>
<th></th>
<th>UPS</th>
<th>XFMR</th>
<th>PS</th>
<th>Total Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Efficiency</td>
<td>85.00%</td>
<td>98.00%</td>
<td>73.00%</td>
<td>60.81%</td>
</tr>
<tr>
<td>DC Option</td>
<td>92.00%</td>
<td>100.00%</td>
<td>92.00%</td>
<td>84.64%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Compute Load (W)</th>
<th>Input Load (W)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Efficiency</td>
<td>10,000</td>
<td>16444.93</td>
<td></td>
</tr>
<tr>
<td>Optimized DC Option</td>
<td>10,000</td>
<td>11814.74</td>
<td>28.16%</td>
</tr>
</tbody>
</table>
Connectors exist

PowerPak configurations for 400 VDC

30 amp Receptacle
Sun Micro

10 Amp Receptacle
Intel

30 amp Plug w/latch
Sun Micro

10 Amp Plug w/latch
Intel

Red spacer location will be replaced by future 4 circuit signal module
Connectors with the right form factor are being developed.
DC Power - path forward:

- DC power pilot installation(s)
- Standardize distribution voltage
- Standardize DC connector and power strip design
- Server manufacturers develop power supply specifications (including disturbances)
- Power supply manufacturers develop prototypes
- UL and communications certification
- Address other types of IT equipment (storage, switches, etc.)
Industry Partners in the Demonstration

Equipment and Services Contributors:

Alindeska Electrical Contractors
APC
Baldwin Technologies
Cisco Systems
Cupertino Electric
Dranetz-BMI
Emerson Network Power
Industrial Network Manufacturing (IEM)

Intel
Nextek Power Systems
Pentadyne
Rosendin Electric
SatCon Power Systems
Square D/Schneider Electric
Sun Microsystems
UNIVERSAL Electric Corp.
Other firms collaborated

Stakeholders:

- 380voltsdc.com
- CCG Facility Integration
- Cingular Wireless
- Dupont Fabros
- EDG2, Inc.
- EYP Mission Critical
- Gannett
- Hewlett Packard
- Morrison Hershfield Corporation
- NTT Facilities
- RTKL
- SBC Global
- TDI Power
- Verizon Wireless
Lawrence Berkeley National Laboratory
• Bill Tschudi, Principal Investigator
  wftschudi@lbl.gov

EPRI Solutions
• Brian Fortenbery
  bfortenbery@eprisolutions.com

Ecos Consulting
• My Ton
  mton@ecosconsulting.com
website:
http://hightech.lbl.gov/datacenters/
Discussion/ Questions??