Efficiency Gains with 480/277V Power at the Cabinet Level
Agenda

• Overview
• Baseline
• 480VAC 3-phase Wye
• Efficiency Gains of 480V/277V
• Distributing 480V/277V at the Cabinet
• Implications of adopting 480V/277V
• Reasons for considering 415V/240V
• Conclusions
Background

• Design limitations to how efficient power components can become

• Greater densities in the cabinet are requiring more and/or higher capacity power drops

• Increasing power costs are driving demand for greater efficiencies

• Demand for 480 and 400 VAC CDUs in US market is steadily increasing
Data Center Pulse

- Data Center Pulse (www.datacenterpulse.com)
  - Data center user group (started Sept. 08)
  - “…an exclusive group of global data center owners, operators and users. The goal of this community is to track the pulse of the industry and influence the future of the datacenter through discussion and debate.”
  - Represented by over 390 companies
  - Inaugural conference compiled list of top ten goals and demands from the industry and manufacturers (Feb 2009)
1. Align the data center industry organizations (AFCOM, The Green Grid, The Uptime Institute and ASHRAE) under a single international umbrella organization that could speak with one voice for the data center community; bring competing organizations to sit at the same table and collaborate; and to curate a body of data center standards.

2. Develop a data center certification, requiring new data centers to meet certain efficiency criteria, like the fuel efficiency standards on vehicles. It would be a consistent baseline to measure efficiency and drive improvement.

3. Come up with a standard definition of the “data center stack” from top to bottom.

4. Update or dump the Uptime Institute Tier Levels. See Mark Fontecchio’s recent story for more on this topic.

5. Demand data center infrastructure vendors develop more modular products. Stop the fixed, over-provisioned designs. Users want plug-and-play data center capacity.

6. The members want an objective way to perform peer-to-peer data center efficiency comparisons. A standard measurement protocol to compare your PUE is against Google and Microsoft. Healthy competition drives efficiency.

7. Users want a common communication standard to monitor all layers of the power delivery system, connecting building management and IT systems.

8. Standardize conductive (liquid) cooling. Encourage ASHRAE to finish and publish a standard on liquid cooling technology. People want to get rid of air.

9. Push vendors to develop higher voltage (480/277volt) servers, allowing users to get rid of one transformer loss and driving up efficiency.

10. Create a repository: A neutral location to house and present data center information. Design best practices, specific server hardware configuration load measurements versus nameplate data, and user-generated vendor evaluations.

Baseline: 208 V Power Distribution

1. 480V Local Power Lines
2. Data Center
3. Computer Racks and Servers
Baseline: 208 V Power Distribution

- Typical 208 VAC 3-phase power distribution path in a US data center

1. 480 VAC 3-phase at the building entrance
2. Power is stepped down
   - 480 VAC enters PDU transformer and exits as 208 VAC 3-Ph
3. 120 VAC or 208 VAC (single or 3-phase) delivered to equipment racks
   - Cabinet PDU in racks distributes 208 VAC 3-phase as 120V or 208V to devices
4. Power supplies inside IT equipment transforms and rectifies power from 120-240 VAC to 3.3, 5 or 12 VDC
## Baseline: 208 V Power Distribution

### Power at the Building Entrance:
*277/480 VAC*

### Power Delivered to IT Equipment:
*120/208 VAC*

- **Phase to phase:** 480 V
- **Phase to neutral:** 277 V

- **Phase to phase:** 208 V
- **Phase to neutral:** 120 V
Baseline: 208 V Power Distribution

Cabinet-Level Power Distribution

Input Power
120/208 VAC
1- or 3-phase

Output Power
120 VAC or 208 VAC
1-Phase

120 VAC or
208 VAC
1-Phase

Device Internal
Power Supply Unit

3.3, 5,
12 VDC

3

4
Baseline: 208 V Power Distribution

• Cabinet Power Distribution Unit – 208 VAC
  – Wye configurations can deliver both 120 VAC and 208 VAC
  – Delta configuration only delivers 208 VAC
Contemporary Power Distribution Efficiencies

FIGURE 28. END-TO-END EFFICIENCY COMPARISON, EXCLUDING LEGACY 480VAC – 208VAC
480V Power Distribution

• Why not just take 480 VAC, 3-Phase directly to the cabinet?
  – Delivers 277 VAC Phase to neutral
  – Eliminates the need for transformers and auto-transformers
  – Greater efficiencies

• Disadvantages
  • Not very common configuration
  • Equipment costs and availability
  • Devices’ power supplies not equipped to take such high voltages directly
  • Local building codes
## Comparison

<table>
<thead>
<tr>
<th>Circuit Capacity</th>
<th>De-rated Value</th>
<th>208 VAC 3-Phase</th>
<th>415 VAC 3-Phase</th>
<th>480 VAC 3-Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 A</td>
<td>16 A</td>
<td>5.8 kW</td>
<td>11.5 kW</td>
<td>13.3 kW</td>
</tr>
<tr>
<td>30 A</td>
<td>24 A</td>
<td>8.6 kW</td>
<td>17.3 kW</td>
<td>19.9 kW</td>
</tr>
<tr>
<td>50 A</td>
<td>40 A</td>
<td>14.4 kW</td>
<td>28.8 kW</td>
<td>33.2 kW</td>
</tr>
<tr>
<td>60 A</td>
<td>48 A</td>
<td>17.3 kW</td>
<td>34.6 kW</td>
<td>39.9 kW</td>
</tr>
</tbody>
</table>

415 VAC 3-phase delivers twice the power of a 208 VAC 3-phase system, while 480VAC delivers 2.3 times

- **208 VAC:** 208V (phase to phase) × 24A × 1.732 = 8,646 W
- **415 VAC:** 240V (phase to neutral) × 24A × 3.0 = 17,280 W
- **480 VAC:** 277V (phase to neutral) × 24A × 3.0 = 19,944 W
HP Power Supply Efficiency Curves

Marcoux and Sumrell, 7x24 Exchange, “277V Power Supplies”
## End to End Efficiency

<table>
<thead>
<tr>
<th>Power</th>
<th>UPS</th>
<th>Distribution</th>
<th>IT Power Supply</th>
<th>Overall Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>480/277 VAC</td>
<td>96.20</td>
<td>X</td>
<td>99.50</td>
<td>92.00 = 88.10%</td>
</tr>
<tr>
<td>400/230 VAC</td>
<td>96.20</td>
<td>X</td>
<td>99.50</td>
<td>90.25 = 86.39%</td>
</tr>
<tr>
<td>480 to 208VAC</td>
<td>96.20</td>
<td>X</td>
<td>96.52</td>
<td>90.00 = 85.00%</td>
</tr>
<tr>
<td>48V DC</td>
<td>92.86</td>
<td>X</td>
<td>99.50</td>
<td>91.54 = 84.58%</td>
</tr>
<tr>
<td>380V DC</td>
<td>96.00</td>
<td>X</td>
<td>99.50</td>
<td>91.75 = 87.64%</td>
</tr>
<tr>
<td>Hybrid 575V DC</td>
<td>95.32</td>
<td>X</td>
<td>92.54</td>
<td>91.54 = 80.75%</td>
</tr>
</tbody>
</table>
Distributing 480V/277V at the Cabinet Level

- C13 and C19 are not rated to 277V
- No agreed upon standard receptacle alternative
- Competing solutions available
Implications of adopting 480V/277

- Reduced energy losses resulting in op-ex savings
- Increased capacity
- Reduced equipment expenses
- Reduced space requirements
- Fewer breakers at the RPP
- Fewer cable runs in the plenum
- Reduced copper
Potential drawbacks for 480V/277V

• Cost delta between 240V and 277V power supplies of 5-15%
• Gear outside of servers has yet to adopt 277V
• Inability to move legacy gear into 277V enabled facilities
• Arc flash -
• 480V/277V is not an international standard whereas 400V/230V is
A Case for 415V

<table>
<thead>
<tr>
<th>415 VAC 3-Phase</th>
<th>480 VAC 3-Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little or no changes required to UPS and delivery system</td>
<td>Greater efficiency by eliminating transformers and autotransformers</td>
</tr>
<tr>
<td>Used in the rest of the world outside of US</td>
<td>Not a common application</td>
</tr>
<tr>
<td>Efficiency gains operating equipment at 240 VAC (over 120 and 208 VAC)</td>
<td></td>
</tr>
<tr>
<td>Existing plugs and connector already exists for equipment</td>
<td>Additional efficiency gains over 240 VAC by operating at a higher voltage. Unfortunately very few IT devices operate at 277 VAC</td>
</tr>
<tr>
<td>US standards already apply to this configuration</td>
<td>New standards will need to be developed and adopted to cover 277 VAC</td>
</tr>
</tbody>
</table>
A Case for 415 VAC Distribution

Baseline: 208 VAC 3-Phase

<table>
<thead>
<tr>
<th>480 VAC</th>
<th>UPS</th>
<th>480 VAC</th>
<th>PDU Transformer</th>
<th>208 VAC</th>
<th>PDU</th>
<th>208 VAC</th>
<th>CDU</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 VAC</td>
<td>208 VAC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

415 VAC 3-Phase

<table>
<thead>
<tr>
<th>480 VAC</th>
<th>UPS w/ Autotransformer</th>
<th>415 VAC 3-phase</th>
<th>PDU</th>
<th>415 VAC</th>
<th>CDU</th>
<th>240 VAC</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>480 VAC</th>
<th>UPS w/ Autotransformer</th>
<th>PDU w/ Autotransformer</th>
<th>415 VAC 3-phase</th>
<th>CDU</th>
<th>240 VAC</th>
</tr>
</thead>
</table>

240 VAC 1-phase
A Case for 415 VAC Distribution

- Areas of potential savings using 415 VAC distribution path
  - Reducing the number of transformers
    - Replace the PDU transformer with a UPS or PDU autotransformer (1 to 2% efficiency gains)
  - Increasing operating voltages
    - 2-3% efficiency gains at the device level by operating equipment at 208 VAC vs. 120 VAC
    - Additional 1% gain by operating at 240 VAC vs. 208 VAC
      - Most IT devices have supplies with upper limits of 240-264 VAC
  - Reduction in line losses by running at lower currents
  - Same system presently used in the rest of the world
  - Fewer power drops
    - Fewer cable runs in the plenum
A Case for 415 VAC Distribution

- Potential infrastructure savings over 208 VAC distribution
  - Fewer power drops
  - Lower cost plugs and receptacles
- Smaller wire size required to distribute power
- Elimination of transformers
  - Reduction in space taken up by transformers
  - Reduce costs to support weight on raised floors
  - Additional heat loads
- Fewer breaker panel positions required
A Case for 415 VAC Distribution

• What’s different?
  – Wye configurations to deliver 240 VAC phase to neutral
  – This is 2x the capacity of the 208 VAC (which delivers only 120 VAC phase to neutral)
  – One 415V 3-phase, 30 A drop will deliver as much power as one 208V 3-phase, 60A drop
  – Does not support 120VAC however cabinet level transformers can be used for those few devices
References

- Open Compute Project, http://opencompute.org
- Server Technology, Power Efficiency Gains by Deploying 415VAC Power Distribution in North American Data Centers, 2009
- BB&T and Syska & Hennessy – 277V Power Supplies
For more information visit www.servertech.com