Transformer UPS vs. Transformerless UPS
Balancing high levels of availability with efficiency

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- Design factors that affect AVAILABILITY
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- Conclusion
Today’s IT, facilities and data center managers face the daunting challenge of maintaining a high availability data center while simultaneously increasing energy efficiency. This challenge, coupled with the need to quickly meet growth demands and provide an easily maintainable facility, makes selecting an uninterruptible power supply (UPS) platform a critical decision element.

Not all UPS platforms are alike. One such design difference being analyzed today is differences between traditional transformer-based UPS to transformerless UPS technology for large enterprise data centers. This paper with embedded links and videos will highlight the most essential points IT managers need to know when evaluating the differing benefits and costs associated with transformer-based UPS compared to transformerless UPS design. Topics highlighted include:

- Energy efficiency comparisons
- Design factors that affect availability
- Maintainability, service and safety
- Total cost of ownership
- Critical questions to ask

The right UPS design strategy should enable a data center to balance lower costs and higher efficiencies with no compromise to overall availability and ability to grow.
**Fact: Energy efficiency is a top-of-mind concern** for data center managers and transformerless UPS designs can achieve higher efficiencies by replacing the UPS transformer with solid-state circuits. As the graph demonstrates, when comparing like-for-like operating parameters, the transformerless UPS achieves higher efficiencies compared to modern transformer UPS designs but only at loaded capacities well over 40 percent.

- Redundant UPS are typically loaded less than 50 percent to ensure if one UPS goes down, the redundant UPS can assume 100 percent of the load.

- Today’s newest generation of transformer-based UPS have been engineered to optimize efficiency at less than half loads. Legacy transformer UPS do not optimize in this operating range.
Using an example of a typical large data center operation utilizing 750 kVA 2N redundant UPS, where UPS loaded at 40 percent capacity, a transformer-based UPS actually reduces energy consumption costs by roughly $2,900 over ten years.

**Points to consider:*
- Every data center is different, so compare UPS efficiency with actual efficiency and local utility rates.
- Efficiency impact analysis must account for PDU transformer losses and potential input isolation transformers.

**Bottom line:** Small differences in efficiency can have minimal impact on dollars saved. A transformerless UPS only achieves better efficiency than transformer-based UPS at loaded capacities far greater than 40 percent.

<table>
<thead>
<tr>
<th>Example: 750 kVA, 2N</th>
<th>Transformerless UPS</th>
<th>Transformer UPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>kVA</td>
<td>750</td>
<td>750</td>
</tr>
<tr>
<td>kW</td>
<td>675</td>
<td>675</td>
</tr>
<tr>
<td>% Load</td>
<td>40%</td>
<td>40%</td>
</tr>
<tr>
<td>kW</td>
<td>270</td>
<td>270</td>
</tr>
<tr>
<td>Efficiency @ %Load*</td>
<td>91.8%</td>
<td>91.9%</td>
</tr>
<tr>
<td>UPS Input kW-H</td>
<td>2,576,471</td>
<td>2,573,667</td>
</tr>
<tr>
<td>Utility Rate ($/kwhr)</td>
<td>0.104</td>
<td>0.104</td>
</tr>
<tr>
<td>Yearly Utility Cost</td>
<td>$267,953</td>
<td>$267,661</td>
</tr>
<tr>
<td>1-year cost difference</td>
<td>($291)</td>
<td></td>
</tr>
<tr>
<td>10-year cost difference</td>
<td>($2,916)</td>
<td></td>
</tr>
</tbody>
</table>

* Efficiencies assume like for like operating parameters (double conversion mode, fan utilization, etc.)

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**Introduction**

ENERGY EFFICIENCY comparisons

Design factors that affect AVAILABILITY
MAINTAINABILITY, service and safety
TOTAL COST of ownership
CRITICAL QUESTIONS to ask

Conclusion

> Click to watch “White Board on Energy Savings”

Can’t get to YouTube at work?
Fact: Despite recent advances in technology, today’s transformerless UPS designs are limited to UPS modules under 300 kVA. To achieve large kW sizes or to achieve redundancy, many small transformerless modules must be paralleled together.

Compare the necessary modules needed to achieve the 750 kVA 2N example under both transformer and transformerless designs:

<table>
<thead>
<tr>
<th>Transformerless Using 250 kVA modules</th>
<th>Transformer Using 750 kVA modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>250 250 250</td>
<td>750</td>
</tr>
<tr>
<td>250 250 250</td>
<td>750</td>
</tr>
</tbody>
</table>

Bottom line: When sizes get large, more transformerless modules are needed, which means more opportunities for module failure and potential system failures. How many modules are needed for 1000 kVA 2N?
Design factors that affect AVAILABILITY

- The number of modules greatly impacts the overall system availability. Using the reliability prediction methodologies found in IEEE Std 493™ Recommended Practice for the Design of Reliable Industrial & Commercial Power Systems, the reliability of the power system can be estimated. Assuming a 10-year MTBF and performing the necessary logarithmic computations yields the following:

<table>
<thead>
<tr>
<th>Transformerless UPS</th>
<th>Transformer UPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modules</td>
<td>3+3</td>
</tr>
<tr>
<td>Module MTBF</td>
<td>10 years</td>
</tr>
<tr>
<td>Module Failure / Yr</td>
<td>0.574</td>
</tr>
<tr>
<td>Modules failing in 10 years</td>
<td>4</td>
</tr>
</tbody>
</table>

- **Bottom line:** Get used to seeing the Service Technician when deploying small transformerless modules in large operations where capacity is greater than 300 kVA. With more modules come more failures.
Design factors that affect AVAILABILITY

- What if the worst case happens and all the expected module failures happen simultaneously?
  - The 1+1 system loses 1 module, the redundant module effectively assumes the load. **No outage.**
  - The 3+3 system loses 4 modules, only 2 modules remain. Critical load will not be maintained. **IT outage.**

- Using a very conservative estimate on **average financial impact of IT downtime of $108,000** and an hour of downtime, the potential business losses are significant.

<table>
<thead>
<tr>
<th>Example: 750 kVA, 2N</th>
<th>Transformerless UPS</th>
<th>Transformer UPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worst Case: Simultaneous Failures</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Downtime Est (hours)</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Avg cost per hr of IT downtime</td>
<td>($108,000)</td>
<td>($108,000)</td>
</tr>
<tr>
<td>Expected Business Losses</td>
<td>($108,000)</td>
<td>$0</td>
</tr>
</tbody>
</table>

- **Points to consider:**
  - Cost of IT downtime varies by industry. Losses in Telecom can be as high as $2,000,000 per hour. Losses in the Healthcare industry can be as high as $600,000 per hour.
  - Transformers prevent DC power from entering the critical bus, which will cause outages.

- **Bottom line:** A worst case scenario of a down data center is unacceptable for many. The more components you add to a design, the more opportunities for failures are introduced. Too many components could take down an entire data center.
Fact: When the modules fail, they will need to be repaired. The more failures the more repairs. Using the example and our expected module failures, a comparison of emergency maintenance expenses can be made:

<table>
<thead>
<tr>
<th></th>
<th>Transformerless UPS</th>
<th>Transformer UPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module Failures in 10 yrs</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Time and Material Rate</td>
<td>($250)</td>
<td>($250)</td>
</tr>
<tr>
<td>Mean Time to Resolution (hr)</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Cost of Emergency Service Calls</td>
<td>($16,000)</td>
<td>($4,000)</td>
</tr>
<tr>
<td>Billable Expense Difference</td>
<td>$0</td>
<td>($12,000)</td>
</tr>
</tbody>
</table>

Points to consider:

- A transformerless UPS has the ability to pass more fault current to the critical load. A transformer UPS can clear and isolate more internal faults than a transformerless design.
- Preventing arc flash explosions is a critical part of a facility manager’s duty. The impedance produced by transformers will limit fault currents and arc flash energy levels.

Bottom line: Transformers require fewer service calls, limit downstream fault current, isolate currents and improve arc flash safety.

> Click to watch “White Board on Maintainability”

Consider Safety
TOTAL COST of ownership

- To properly analyze Total Cost of Ownership (TCO), the compromise between efficiency and availability must be weighed against system cost.

<table>
<thead>
<tr>
<th>Efficiency</th>
<th>91.8% efficient @ 40% load</th>
<th>91.9% efficient @ 40% load</th>
<th>($2,916)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability</td>
<td>One 1-hour outage</td>
<td>Zero outages</td>
<td>($108,000)</td>
</tr>
<tr>
<td>Maintainability</td>
<td>4 module repairs</td>
<td>1 module repair</td>
<td>($12,000)</td>
</tr>
<tr>
<td></td>
<td>Net benefit of using Transformerless UPS</td>
<td></td>
<td>($122,916)</td>
</tr>
</tbody>
</table>

Purchase price savings of Transformerless UPS + $122,916 = True Cost of Ownership

- There are other costs that should be factored into any TCO analysis:
  - True efficiencies running under various energy optimization modes for a specific amount of hours in a year
  - Risk of arc flash explosions
  - Cost of transformers elsewhere in the power system to achieve isolation
  - Number of downstream faults not cleared by UPS that result in failures

- **Bottom line:** The financial impact transformer-based UPS have on Efficiency, Availability and Maintainability should be included in cost comparisons of the two designs.

Continue…
The example used throughout the analysis, 750 kVA, 2N, is important to note. Transformerless UPS topologies, while available only in modules under 300 kVA, have many benefits that are well suited to smaller operations and the impact to Efficiency, Availability and Maintainability will be greatly altered if the module count of the UPS is small, total power demand is low, or if the UPS is loaded far beyond 40 percent.

Transformerless UPS benefits that may impact TCO:

- **Purchase Cost** – Transformers are expensive components of a UPS and eliminating them will save capital costs of the UPS (but be aware, transformers will still need to be included somewhere in the data center).

- **Efficiency** – At capacities over 40 percent, transformerless UPS efficiencies may be greater than some legacy transformer-based UPS. Don’t get caught up in efficiency modes, know your typical operating mode.

- **Footprint** – Transformerless UPS have smaller footprints, so the cost of real estate needs to be included.

- **Weight** – By eliminating the heavy transformer, the transformerless UPS could reside on a raised floor. Shipping costs will also likely be lower.

- **Heat Output** – The need for precision cooling of the power equipment may be reduced because the heat produced by the transformerless UPS is less.

IT and data center managers should evaluate how their needs and operating environment align with the capabilities and performance of the two UPS design options.
**CRITICAL QUESTIONS to ask**

**What is my power growth plan?**

Why? The modular design of the transformerless UPS addresses the quickly changing power requirements of IT, but the modularity comes at the expense of reliability when growth gets too large. If the growth path is ambiguous yet final total capacity is known to be small, transformerless UPS could be included in UPS evaluations.

**What are my availability requirements and plans on UPS redundancy?**

Why? Because of its design, the component count of transformerless UPS is high. Parts count has a direct impact on reliability. If the availability needs are high and redundancy is needed, a transformer-based UPS is the optimal design.

**How many components and switching devices are in my UPS design?**

Why? Component count has a direct impact on reliability. If the system is large, a transformer-based UPS should be the optimal design to reduce potential points of failure.

**What are my real estate limitations?**

Why? Transformerless UPS are smaller than transformer UPS. They also weigh less, making them possible to place in the rack row. If the equipment room is not available or the UPS will reside with the IT equipment, transformerless UPS could be included in UPS evaluations.

**Do I have a safety requirement to reduce arc flash fault current?**

Why? Personal safety should always be included in IT infrastructure design. If a facility wants to limit fault current, a transformer-based UPS should be the optimal design.
Conclusion

Transformer-based UPS designs are proven topologies for achieving high efficiency without compromising availability in large enterprise data center applications and midsize to small operations as well. Due to design limitations on the size of transformerless UPS technology, their use should only be considered in low power, small and medium size operations where achieving the highest availability is not the top priority.

Additional Resources

If you’re interested in learning more about trends and topics related to powering, cooling or monitoring data centers, check out these white papers from Emerson Network Power.

Best practice case studies of how other companies have solved data center challenges are available in narrative and video forms. Case studies are from small to large companies across numerous industries.

If you have specific questions, a Liebert Representative from Emerson Network Power or a Liebert certified IT reseller can help you out. Click here to find your local contact.

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