In many of the world’s markets, such as the United States, the quality of the mains power is consistently good, though occasional loss of power is not uncommon. Recognizing and configuring accordingly to mains power quality results in an optimization of UPS size, weight, power and cost.

One such consideration for data center managers is the long-standing tradeoff in UPS architecture. It is useful to group AC UPS architectures into two main classes: single conversion and double conversion. This distinction is due to their relative complexities and capabilities in the conversion of AC power. While both architectures fulfill the need of providing back-up power to a rack, the subtleties of how a UPS behaves when not providing back-up power can make an appreciable difference in operating cost, battery life and even cooling infrastructure.
INTRODUCTION
While there are many different approaches to the detailed design of a UPS, the market can be generally classified as either single conversion or double conversion systems. Single conversion is so termed because it performs only a single power conversion, specifically from stored battery power to AC power for the output via an inverter stage. A double conversion UPS continuously converts AC power from the wall into DC power via a rectifier stage, and then converts DC back to AC via an inverter stage. This topology performs these power conversion processes 24/7, 365 days per year. Just as with any other decision point a data center manager must consider, there are advantages and disadvantages to each approach. To understand them, it is necessary to understand how each functions in a real-world environment.
NORMAL OPERATION

Any UPS, regardless of architecture, has three primary operational behaviors: 1. normal operation, in which AC mains is present, 2. battery operation, in which AC mains is lost and the battery is used as the power source, and 3. charge, in which AC mains is returned and system is both providing AC to the load and re-charging the battery.

Normal operation occurs when AC mains is present and the battery is fully charged. The majority of the life of a UPS is spent in this state, particularly in regions with high grid stability and power quality.

For a single conversion UPS, normal operation is commonly referred to as standby mode. In this mode, the AC mains is filtered and then routed through a bypass switch—which includes current and voltage monitoring capabilities—directly to the AC load on the UPS output. There is no power conversion in this mode, making it inherently highly efficient.

For a double conversion UPS, normal operation entails passing AC mains first through a rectifier stage—in which AC is converted to DC—and then through an inverter stage—in which DC is converted back to AC—to the AC load on the UPS output. Thus, power is continually conditioned and converted, though at a cost to efficiency. Figure 1 illustrates the respective power paths for each architecture.

Figure 1. A comparison of conversion architectures during normal operation
Battery Operation

In the event of a loss of AC mains, the UPS—regardless of architecture—begins pulling DC power from the battery, converting it to AC power via the inverter stage, and passing it to the AC load on the system output. The primary architectural difference in battery operation is not actually in steady state operation; rather it is in how each architecture handles the transition from normal operation to battery operation.

To detect the loss of AC mains, a single conversion UPS relies on voltage and current monitoring methods for operation of the bypass switch. Within a fraction of a line cycle (8 – 12 ms), the UPS opens the bypass switch, turns on the inverter and begins providing AC power from the battery.

In contrast, a double conversion system is always passing power through the inverter. Consequently, the loss of AC mains triggers the inverter to stop pulling power from the DC output of the rectifier and to instead pull power from the battery. This switchover occurs instantaneously and is effectively undetected by the AC load on the system output. Figure 2 demonstrates the respective power paths for each architecture during battery operation.

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Figure 1. A comparison of conversion architectures during normal operation

Figure 2
Single and Double conversion, UPS Mode
Charge Mode
Generally speaking, charge mode is both common to and independent of UPS topologies. When AC mains is present and the battery is not fully charged, a UPS can simultaneously pass AC power to the output load via the same mechanisms as normal operation and simultaneously draw additional power through a rectifier/charger stage to charge the battery. In addition to the re-charging of the battery required after a power loss event, a UPS will also enter into charge mode to balance or top-off a battery as it self-discharges over time.

The most pertinent structural distinction between single and double conversion is rectifier size. Because a single conversion system utilizes the rectifier solely for charging, it is typically a much lower power design. This translates into improvements in reliability, size, weight, and cost. Alternately, the rectifier of a double conversion system must be sized to accommodate providing full power to the AC load and the power required to re-charge the battery, resulting in a much larger supply.

CHOOSING A UPS ARCHITECTURE
Now that the basic operation of both UPS types has been defined, the suitability of each architecture for a given application can be considered using common decision criteria.

Size & Weight
A single conversion unit is typically volumetrically smaller and lighter as it need not pass full power through the rectifier/charger stage.

Cost
A single conversion unit costs less than a double conversion unit of comparable power level, again due to the comparatively small rectifier needed for charging the battery. In addition, wear-out of key power conversion circuitry—a large system cost driver—is reduced in a single conversion system because no power conversion is needed during oft-used normal operation.

Power Quality/Line Defects
In instances in which AC mains is of inconsistent quality, a double conversion system is often preferred. Double conversion systems can absorb most line defects into the rectifier—including brownouts, over-voltage, and harmonic distortion—without the AC load on the output being affected. Single conversion systems can perform some amount of surge protection, but are primarily designed to compensate for blackout conditions.
Transfer Time
Industry standards dictate that most IT equipment, such as servers and switches, must sustain a loss of power up to 12 ms. The amount of time elapsed between loss of AC and creation of a suitable AC waveform on the system output is known as transfer time. In a single conversion system, this is the total time required to detect loss of AC, switch the bypass, and begin producing AC power through the inverter. In a double conversion system, this is determined solely by the time required to detect loss of AC in the rectifier. Because double conversion systems are constantly powering the AC load with the inverter, there is typically no delay or brownout experienced by the AC load. However, unless the load consists of highly sensitive equipment, the relatively slower single conversion transfer time is of no consequence.

Efficiency
In a double conversion system, as the name implies, power is being converted twice. Consequently, the efficiencies of two independent high-power stages must be considered. To illustrate, a 6.0 kW UPS with 95% efficient rectifier and inverter stages has a combined efficiency of only 90%, meaning 585 Watts of heat is generated. The equivalent single conversion unit would lose only 300 W. This lost power is comparable to the power draw of a blade server.

<table>
<thead>
<tr>
<th>Single Conversion</th>
<th>Double Conversion</th>
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<tbody>
<tr>
<td><strong>Benefits:</strong></td>
<td><strong>Benefits:</strong></td>
</tr>
<tr>
<td>• Normal operation mode requires no power conversion (no inefficiencies)</td>
<td>• Can correct power quality, including voltage sag, brownouts, and poor power factor correction</td>
</tr>
<tr>
<td>• Smaller form factor, only requires rectifier for charging</td>
<td>• Nearly instantaneous transfer time</td>
</tr>
<tr>
<td><strong>Costs:</strong></td>
<td><strong>Costs:</strong></td>
</tr>
<tr>
<td>• Can correct for AC mains loss and protect against current surges, but not power quality</td>
<td>• Inefficient in normal mode (waste heat generated during AC-DC and DC-AC conversion)</td>
</tr>
<tr>
<td>• Transfer time may be excessive for non-standard equipment in load</td>
<td>• Large rectifier (affects size and cost)</td>
</tr>
<tr>
<td><strong>Application</strong></td>
<td><strong>Application</strong></td>
</tr>
<tr>
<td>– regions with high grid stability and power quality (US, Canada, most of Europe)</td>
<td>– regions with low quality power, equipment highly sensitive to noise or power loss</td>
</tr>
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</table>
Consequently, a simple single conversion system is frequently an excellent option for most applications, particularly in regions with high quality power.

It should be noted that a third architecture, commonly referenced as a hybrid UPS, is becoming more commonly available. A hybrid UPS contains both a bypass switch, which is utilized in normal operation, and a full-size rectifier, which is used only when a power quality issue is detected. Thus, a hybrid offers the efficiency of a single conversion system and the power quality of a double conversion system. However, this functionality again comes at a cost to budget, size, and weight and thus has somewhat limited adoption.

**SUMMARY**

New technologies are driving positive change in size, weight, power and cost for UPS implementations. Adding UPS architecture to these decision points can aid a data center manager in finding the optimal solution for a given application and environment. This results in substantial improvements in terms of UPS power, size, weight capacity, efficiency and reliability for a given cost. The highly efficient, space-saving form factor of a single conversion UPS dominates in the usage profile for a typical installation and is often key to maximizing performance/cost.

**Sources**


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Methode Data Solutions Group, a Methode Electronics Company (NYSE: MEI) supports the telecommunications, data communications and data center industries with versatile data center infrastructure management (DCIM) and physical layer solutions that deliver value from day one. We take your data center to the next level with innovative technology, our ability to provide quality, customized solutions; and a diverse portfolio of products. Visit www.methode.com/data to learn more.

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