Misunderstandings regarding UPS systems are cleared when the different UPS topologies, indicating the basic nature of UPS design, are identified properly. Various vendors produce models with similar designs but with very different performance characteristics.

**UPS types**

A variety of design approaches is used to implement UPS systems, each with distinct performance characteristics. The most common design approaches are:

- Standby
- Line interactive
- Standby-ferro
- Double conversion on-line
- Delta conversion on-line

**Standby**

The standby UPS is the most common type used for desktop computers. In the block diagram (see Fig. 1), the transfer switch is set to choose the filtered AC input as the primary power source (solid line path), and switches to the battery/inverter as the back-up source should the primary source fail. When that happens, the transfer switch must operate to switch the load over the battery/inverter backup power source (dashed path). The inverter only starts when the power fails, hence the name “standby”. High efficiency, small size and low cost are the main benefits of this design. With proper filter and surge circuitry, these systems can also provide adequate noise filtration and surge suppression.

**Line interactive**

The line interactive UPS (see Fig. 2) is the most common design used for small business, web, and departmental servers. In this design, the battery-to-AC power converter (inverter) is always connected to the output of the UPS. Operating the inverter in reverse during times when the input AC power is normal provides battery charging.

When the input power fails, the transfer switch opens and the power flows from the battery to the UPS output. With the inverter always on and connected to the output, this design provides additional filtering and yields reduced switching transients when compared with the standby UPS topology.

In addition, the line interactive design usually incorporates a tap-changing transformer. This adds voltage regulation by adjusting transformer taps as the input voltage varies. Voltage regulation is an important feature when low voltage conditions exist, otherwise
the UPS would transfer to battery and then eventually “down” the load. This more frequent battery usage can cause premature battery failure. However, the inverter can also be designed so that its failure will still permit power flow for the AC input to the output, which eliminates the potential of single point failure and effectively provides for two independent power paths. High efficiency, small size, low cost and high reliability coupled with the ability to correct low or high line voltage conditions make this the dominant type of UPS in the 0.5 to 5 kVA power range.

**Standby-ferro**

The standby-ferro UPS was once the dominant form of UPS in the 3 to 15 kVA sector. This design depends on a special saturating transformer that has three windings (power connections). The primary power path is from AC input, through a transfer switch, through the transformer, and to the output. In the case of a power failure, the transfer switch is opened and the inverter picks up the output load.

In the standby-ferro design, the inverter is in the standby mode, and is energised when the input power fails and the transfer switch is opened. The transformer has a special “ferro-resonant” capability which provides limited voltage regulation and output waveform “shaping”. The isolation from AC power transients provided by the ferro transformer is as good as or better than any filter available. But the ferro transformer itself creates severe output voltage distortion and transients, which can be worse than a poor AC connection. Even though it is a standby UPS by design, the standby-ferro generates a great deal of heat because the ferro-resonant transformer is inherently inefficient. These transformers are also large relative to regular isolation transformers so standby-ferro UPS are generally quite large and heavy.

These systems are frequently represented as on-line units, even though they have a transfer switch, the inverter operates in the standby mode, and they exhibit a transfer characteristic during an AC power failure. Fig. 3 illustrates this standby-ferro topology.

High reliability and excellent line filtering are this design’s strengths. However, the design has very low efficiency combined with instability when used with some generators and newer power-factor corrected computers, causing the popularity of this design to decrease significantly.

The principal reason why standby-ferro...
UPS systems are no longer commonly used is that they can be fundamentally unstable when operating a modern computer power supply load. All large servers and routers use “power factor corrected” power supplies which draw only sinusoidal current from the utility, much like an incandescent bulb. This smooth current draw is achieved using capacitors, devices which “lead” the applied voltage. Ferro resonant UPS systems use heavy core transformers which have an inductive characteristic, meaning that the current “lags” the voltage. The combination of these two items comes from what is referred to as a “tank” circuit. Resonance or “ringing” in a tank circuit can cause high currents, which jeopardise the connected load.

**Double conversion on-line**

This is the most common type of UPS above 10 kVA. The block diagram is the same as the standby (see Fig. 4), except that the primary power path is the inverter and not the AC main.

In the double conversion on-line design, failure of the input AC does not cause activation of the transfer switch because the input AC is charging the back-up battery source which provides power to the output inverter. Therefore, on-line operation results in no transfer time during an input AC power failure. Both the battery charger and the inverter convert the entire load power flow in this design.

This UPS provides nearly ideal electrical output performance, but the constant wear on the power components reduces reliability compared to other designs. The input power drawn by the large battery charger may also be non-linear and this can interfere with building power wiring or cause problems with standby generators.

**Delta conversion on-line**

This UPS design (see Fig. 5) is a newer, ten-year-old technology introduced to eliminate the drawbacks of the double conversion on-line design and is available in sizes ranging from 5 kVA to 1,6 MW. Similar to the double conversion on-line design, the delta conversion on-line UPS always has the inverter supplying the load voltage. However, the additional delta converter also contributes power to the inverter output. Under conditions of AC failure or disturbance, this design exhibits behaviour identical to the double conversion on-line. A simple way to understand the energy efficiency of the delta conversion topology is to consider the energy required to delivering a package from the fourth to the fifth floor of a building (see Fig. 6). Delta conversion technology saves energy by carrying the package only the difference (delta) between the starting and ending points. The double conversion on-line UPS converts the power to the battery and back again whereas the delta converter moves components of the power from input to output.

The delta converter acts to control the input power characteristics. This active front end draws power in a sinusoidal manner, minimising harmonics reflected on to the utility, ensuring optimal utility and generator system compatibility. The second function of the delta converter is to control input current to regulate charging of the battery system.

The delta conversion on-line UPS provides the same output characteristics as the double conversion on-line design. However, the input characteristics are often different. Delta conversion on-line designs provide dynamically power factor corrected input, without the inefficient use of the filter banks associated with traditional solutions. The most important benefit is a significant reduction in energy loss. The input power control also makes the UPS compatible with all generator sets and reduces the need for wiring and generator oversizing. Delta conversion on-line technology is the only core UPS technology today protected by patents and is therefore not likely to be available from a broad range of UPS suppliers.

**Summary of UPS types**

Some attributes of a UPS such as efficiency are dictated by the choice of UPS type. Since implementation and manufactured quality impact characteristics such as reliability more strongly, these factors must be evaluated in addition to these design attributes.

**Use of UPS types in industry**

The current UPS industry product offering has evolved over time to include many of these designs. The different UPS types have attributes that make them more or less suitable for different applications and the APC by Schneider Electric product line reflects this diversity as shown in Table 1.

Contact Jacqui Gradwell, APC by Schneider Electric, Tel 011 254-6400, jacqui.gradwell@apcc.com

---

**Table 1: UPS architecture characteristics.**

<table>
<thead>
<tr>
<th>Commercial product</th>
<th>Benefits</th>
<th>Limitations</th>
<th>APC's findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standby</td>
<td>APC Back-UPS Tripp-Lite internet office</td>
<td>Low cost, high efficiency compact</td>
<td>Uses battery during brownouts, impractical over 2 kVA</td>
</tr>
<tr>
<td>Line interactive</td>
<td>APC smart-UPS powerware 5125</td>
<td>High reliability, high efficiency, good voltage conditioning</td>
<td>Impractical over 5 kVA</td>
</tr>
<tr>
<td>Standby-ferro</td>
<td>Commercial product availability limited</td>
<td>Excellent voltage conditioning high reliability</td>
<td>Low efficiency, unstable in combination with same loads and generation</td>
</tr>
<tr>
<td>Double conversion on-line</td>
<td>APC Smart-UPS On-Line APC Smart-UPS VT APC Symmetra1 MGE Galaxy MGE EPS Liebert NX</td>
<td>Excellent voltage conditioning ease of paralleling</td>
<td>Lower efficiency with older models, expensive under 5 kVA</td>
</tr>
<tr>
<td>Delta conversion on-line</td>
<td>APC Symmetra MW</td>
<td>Excellent voltage conditioning, high efficiency</td>
<td>Impractical under 5 kVA</td>
</tr>
</tbody>
</table>