IEEE Standard 1100-2006 (Emerald Book), Section 8.6.5 (p. 302) "Lightning and other transient voltage and current-producing phenomena are harmful to most UPS equipment and to its service electronic load equipment... Therefore, it is recommended practice that both the input circuit to the UPS and the associated UPS bypass circuits (including the maintenance bypass circuit) be equipped with effective... [SPDs]."

The demand for conditioned and back-up power is dominated by the expanded utilization of information technology (IT) equipment. UPS equipment has commonly been deployed to support IT equipment in data centers (e.g. financial, insurance, data warehousing, internet providers) and telecommunication systems (e.g. mobile communication shelters, 911 centers). In addition, UPSs are also being deployed for use in numerous other applications.

UPS TOPOLOGIES

The three different topologies or types of uninterruptible power supplies (UPS) are off-line, line-interactive, and double conversion. Off-line and line interactive UPSs provide protection against power outages in non-critical single phase power computing systems [1]. The off-line UPS is a low-cost solution with minimal performance capabilities. The line interactive UPS can be configured to provide power factor correction and limited power conditioning [1].

The double conversion UPS provides conditioned and back-up power to critical workstations, servers, networks, or complete data center information technology (IT) equipment [1]. Double conversion UPS topology uses AC power from the electrical distribution, rectifies the AC power to DC, and converts the DC power back to conditioned AC power. Since the double conversion UPS is used for critical loads it will be a topic of discussion for the remainder of this paper.

UPS systems are composed of a rectifier section, battery and inverter section; the input and output circuit breakers, and a static transfer switch. The rectifier is the section that converts AC power to DC power. The inverter section of the UPS creates AC voltage from DC voltage through a complex "chopping" operation.

To allow for maintenance a bypass circuit is incorporated. The bypass system encompasses the static transfer switch and the manual switch/circuit breaker. Static switches are semiconductor switches that can be used in AC power environments and activate within milliseconds. Circuit breakers are mechanical devices that provide over-current protection and manual switching capabilities, see Figure 1.

**Figure 1.** Double Conversion UPS
HOW SUSCEPTABLE IS THE UPS?

Does a UPS need transient overvoltage protection, and if so, what is the protection level required? Yes. The IEEE Emerald Book, section 8.6.5, provides guidance on the application of SPDs for UPS equipment [2]. The voltage protection level required to protect the UPS varies among manufacturers and product lines. The UPS manufacturer should be consulted for the protection levels needed for a specific UPS. In many cases, the UPS manufacturer has only conducted limited transient testing on the UPS, so there are some design criteria than can be used to provide guidance on choosing the performance parameters of the installed SPD on a UPS.

The semiconductors used for switching, and the capacitive and inductive components used for filtering are directly in the path of transient overvoltages in the UPS. However, protection also needs to be provided for the control circuitry, and the components of the bypass circuitry.

Protection of the UPS is required because:

- Transient overvoltages can cause dielectric breakdown of the semiconductors in a UPS
- Dielectric breakdown causes damage to the functionality of the UPS equipment
- UPS equipment can be located at the service entrance, or in close proximity of the service entrance
- UPS equipment are designed to provide conditioned power to critical processes

Some UPS systems are designed with metal-oxide varistors (MOVs) at the UPS input. These surge components are installed to protect the rectifier and control circuitry of the UPS. Surge components installed at this location are not adequate to protect the complete UPS System, nor are the surge components rated to protect the UPS for use in a high-availability system.

PROTECT YOUR INVESTMENT

Regardless of the semiconductor, filtering, and signal processing components used, the rectifier and inverter sections of the UPS, and the static switch are highly susceptible to overvoltage transients. When the UPS is operating in its primary mode of operation, i.e. providing conditioned power to the load, surge protective devices (SPDs) are required at the UPS input of the UPS to protect the rectifier section, and at the critical load output of the UPS to protect the inverter. When the UPS is operating in bypass mode, SPDs are required on the bypass input and critical load output to protect the static switch, see Figure 2.

HOW MUCH PROTECTION IS NEEDED?

The installed performance attributes required from the SPD need to be coordinated to the threshold susceptibility limits of the UPS equipment to ensure that the SPD is providing the protection needed. To accomplish this, the following parameters of the SPD must be obtained:

- Voltage protection rating of the SPD
- Overcurrent protection requirements of the SPD
- Affects of lead lengths on the Voltage Protection Rating of the SPD

The voltage protection rating (VPR) is similar to the Surge Voltage Rating (SVR) obtained from a series of tests detailed in Underwriters Laboratories Standard for Safety, Surge Protective Devices [3][4]. The VPR of the SPD is from a series of preferred values, see Table 1. Testing of the SPD is conducted with specific transient waveform.

### Typical Voltage Protection Ratings (VPR)

<table>
<thead>
<tr>
<th>Voltage (V)</th>
<th>Rating (A)</th>
<th>Rating (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>330</td>
<td>900</td>
<td>2,500</td>
</tr>
<tr>
<td>400</td>
<td>1,000</td>
<td>3,000</td>
</tr>
<tr>
<td>500</td>
<td>1,200</td>
<td>4,000</td>
</tr>
<tr>
<td>600</td>
<td>1,500</td>
<td>5,000</td>
</tr>
<tr>
<td>700</td>
<td>1,800</td>
<td>6,000</td>
</tr>
<tr>
<td>800</td>
<td>2,000</td>
<td></td>
</tr>
</tbody>
</table>

Table 1.
When properly applying SPDs, over-current protection is required. The over-current protection can be either internal or external to the SPD. If the over-current protection is external, this can be accomplished by an appropriately circuit breaker. If the over-current protection is internal, then an external switch is required to perform maintenance on the SPD.

The rating of the over-current protective device must be matched to the SPD. Overcurrent ratings are dependent on the point of application of the SPD within the electrical distribution [5]. When installed as shown in Figure 2, the interrupt rating (IR) of the circuit breaker should be less than or equal to the short circuit current rating (SCCR) of the SPD.

**Conclusion**

UPS equipment, like other electronic equipment connected to the electrical distribution network, is susceptible to transient overvoltages from lightning and other sources. The IEEE Emerald Book provides guidance on the application of SPDs for UPS equipment. For complete protection of UPS equipment, SPDs are required on the UPS input, the bypass input, and the critical load output, as shown in Figure 2.

When applying SPDs to a UPS, the following recommendations should be considered:

- The Voltage Protection Rating or Surge Protection Rating of the SPD.
- The short circuit current rating of the SPD must to be equal to or greater than the short circuit current capability at the point of application.
- The let-through voltage of the installed SPD is required to be lower than the threshold susceptibility limit of the UPS.

References