TDI POWER

Enter the ESPN Zone

Powerful Opponents Facing the OSP

By Gary Mulcahy and Kelly Atkinson

As service providers offer more options in communication, modern electronic systems are increasingly being applied in outdoor, non-sheltered or semi-sheltered environments. As such, special measures must be taken in the design and construction of electronic assemblies in these environments to assure optimal reliability. In particular, power conversion equipment faces unique challenges in this regard due to high electrical, thermal, and vibration stresses it must successfully endure.

Today, it's not unusual to find high-end electronic equipment in non-traditional environments. Consider the communications equipment we see mounted on masts, poles, or even on roofs across the country. As an example, Figure 1 shows a power system mounted half way up a very frozen communications tower.

There are now several alternative equipment design and construction techniques for highly reliable power conversion equipment that is compatible with increasing environmental stress levels.

Powerful Opponents

Power conversion equipment is often challenged by formidable opponents such as voltage gradients, high current densities, energy storage, high temperatures, and heavy, irregular shaped components. Separately, each of these can impact the performance of power equipment. In combination, these factors have the potential to wreak havoc on the reliability of the power system.

Opponent #1: Compromised Insulation

Most modern electronic applications requiring more than a few hundred watts utilize forced air for cooling. A typical switching power supply operating under ideal conditions has its operating life ultimately limited by the dehydration of aluminum-electrolytic capacitors, with the exception of wear of cooling fans, and accumulation of dust and debris within the unit. In a well-designed unit, these should provide seven years of continuous operation. However, insulation compromise due to infused dust, debris, and vermin reduces the useful life of a power supply.

Even in relatively clean and climate-controlled environments, dust and other potentially conductive debris will be infused into the unit over time. Figure 2 shows a unit that was returned for service after approximately two years of operation in a computer room environment (not generally considered to be a harsh environment). And we expect power systems to perform flawlessly in the OSP?

In addition, infused debris can cause bridging of circuits due to conductive material coming to rest across insulating barriers. Alternately, dust build-up acts as a reservoir for ionic contaminates and moisture entrapment from humidity. Over time, these can enable the growth of conductive dendrites that may ultimately bridge insulating barriers.

Then, there are those pesky dendrites. These microscopic conductive paths are formed when ionic materials, in the presence of moisture and an electric field, disassociate into negatively and positively charged materials.

But, wait – there's more. Dust is the enemy. Its accumulation will degrade the performance of heat sinks and air filters that provide cooling for power dissipating elements. As these get clogged, the operating temperature of components will increase, ultimately leading to reduced component life.

Thankfully, we also know one of this opponent's weaknesses. One effective approach is to coat printed wiring boards with a thin acrylic coating for computer or control room products.

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Finally, don't forget the humidity and moisture issues in outdoor environments. Even in air-conditioned cabinets, moisture condensation may occur as temperatures increase and decrease when cabinet doors are opened for service. Consider equipment located nearby the ocean, where salt and fog penetration can greatly accelerate metal corrosion, as well as provide a rich mixture of ions to promote dendrite growth.

Opponent 2: Extreme Temperatures

Typical outdoor electronic systems must withstand the rigors of the climate in which they are installed. Consider temperature extremes as low as –30ºC (-22ºF) and as high as 45ºC (113ºF)! What's more, solar loading can increase the effective operating temperature of the equipment by as much as 20ºC to 30ºC.

Generally, cabinet-level cooling or heating is implemented in these environments. An air-to-air heat exchanger is one

From left:

Figure 1: Communication system in a severe environment.

Figure 2: Dust build-up in data processing application.

common and generally reliable method to use in the OSP. Unfortunately, it has only modest cooling performance. Traditional compressor derived air-conditioning has very good cooling performance; however, it comes at a greater cost and introduces other reliability and maintenance issues.

Outwitting Both Opponents

The most straightforward method to address severe environments is to enclose these sensitive systems in environmentally controlled enclosures. Telecommunication systems have been doing this for years, with reasonably good results. However, smaller systems, such as WiMAX nodes, have presented new challenges to systems designers in terms of size, cost, and reliability.

Some systems utilize environmentally hardened equipment in semi-sheltered environments that protect sensitive equipment from direct moisture egress, bugs, vermin, and solar loading. Unfortunately, unconditioned outside air comes indirect contact with deployed equipment when cabinets are opened for service. In these applications, a cost-effective alternative is to utilize fan-cooled power conversion equipment that is hardened against the effects of humidity, moderate salt-fog, dust and grit.

Vendors of power equipment have recently developed products that utilize a 2 to 3mm thick coating of Silicon RTV (Room Temperature Vulcanizing) to protect all small electronic components and printed wiring board traces. Larger components and heat sinks take advantage of moving air for cooling purposes.

In cases when the circuit to be powered is located in an air-conditioned and sealed enclosure, an environmentally sealed power module (ESPM) provides an attractive source of external power since it simultaneously reduces the heat load on the air conditioner and provides additional space for environmentally sensitive equipment.

Battery back-up assemblies that provide uninterruptible power to critical systems should also be isolated from the sealed and air-conditioned equipment enclosure. To prevent the build up of fumes or corrosive atmospheres, they are often packaged in a separate ventilated enclosure that protects the batteries from the external environment. Temperature regulation of the batteries can be accomplished with highly reliable thermo-electric heating and cooling which simultaneously assures maximum life and performance.

Getting in the Zone

For many providers, the only truly reliable way to beat these conditions is deploy an ESPM in the field. An ESPM employs an encapsulating material that carries heat away from irregularly shaped internal components to their external heat sink. (See Figure 3.) For lower power units, a thermally conductive silicone RTV potting is utilized, while environmentally friendly, vegetable based oil is utilized on higher power units. Encapsulating material for these units provides thermal conduction, component, and material compatibility.

Interestingly, the thermal conductivity of a solid encapsulating material is constant and independent of the power it encloses; whereas oil shows increasing thermal conductivity as the enclosed power increases due to convection currents being formed in the oil as it heats up. (See Figure 4.) Therefore, thermally conductive oil is used on higher power units due to its superior heat conduction parameters as temperatures increase and its ability to circulate well.

Both encapsulating materials provide compatibility with operation in temperature extremes in excess of the −30ºC to +45ºC and maximum internal temperatures expected during full load operation (up to 100ºC).

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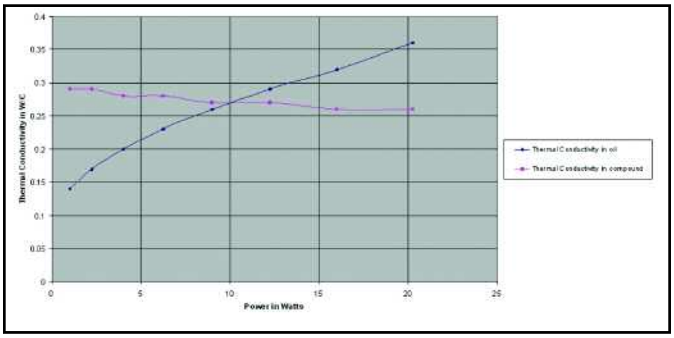
Figure 3: Environmentally sealed modules deployed as part of a system.

Figure 4: Comparison of thermal conductivity of RTV versus oil.



What are the field implications of this? Remote DC uninterruptible power nodes are good examples of where the elimination of power conversion heat load from system cooling requirements provides significant improvements in cost and reliability.

Also, consider the many WiMAX nodes that require a local battery plant to provide continued operation in the event of a utility power failure. These systems generally require 200-700 watts of power be maintained for several hours from a battery plant the size of a suitcase. The charger that maintains these batteries may dissipate up to 70W of power. Since optimal battery life is achieved when battery temperature is maintained well below 45°C, isolating the power supply from the battery compartment helps improves battery performance.

A variation on this solution is utilizing an environmentally sealed rectifier. With that solution, power conversion heat can be removed from the battery compartment, leaving only the self-losses of the batteries to be cooled. This allows the use of either typical convection cooling for the battery compartment or highly reliable, solid-state thermo-electric coolers. A sealed module solution such as this precludes the need for a 500-1,000 BTU air-conditioner, which can cost several hundred dollars and complicate system maintenance.

Win in the Field

Environmentally sealed or hardened power modules present today's telecom system designers with the opportunity to reduce costs and increase system reliability. New generation packaging techniques leverage existing, high reliability power circuits, thus enabling optimization of electronic systems targeted toward outdoor, and other severe environments.

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