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Next Gen Smart Grid Equipment Challenges Power Supply Designers

By Michael Allen
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A considerable amount of new electronics equipment will be designed and deployed over the next five years as utilities build out the smart grid to reduce energy consumption and increase delivery efficiency. The first phase, installing smart meters in homes and buildings, has received the lion's share of the attention so far.

Smart meters monitor energy consumption and send data back to energy suppliers, who can use the information to improve load balancing, fine-tune variable pricing schemes (peak-leveling) and even control appliances remotely. Utilities in the United States will roll out nearly 60 million smart meters by 2015. The UK government has mandated that 47 million meters be installed by 2020. Many other countries have equally ambitious programs. With tens of millions of smart meters already installed in the US alone, attention is now turning to the infrastructure required to communicate with and control all of those meters. Furthermore, energy generation companies are implementing smart sensors at plants and substations to monitor equipment performance and manage assets.

This next wave of smart grid equipment places new demands on the engineers who design it. Specifically, unlike in-home smart meters, much of this new equipment will operate outdoors and under harsh environmental conditions. For example, the data concentrators that collect data from groups of meters and transmit it to the central server will be mounted on utility poles in neighborhoods.

One of the most unexpectedly complicated aspects of designing an electronic device for outdoor use is the power supply, usually an ac/dc converter, which regulates the input voltage and converts it to levels suitable for the system components. The supply must protect the system from transient surges and operate reliably for many years despite extreme operating temperatures.

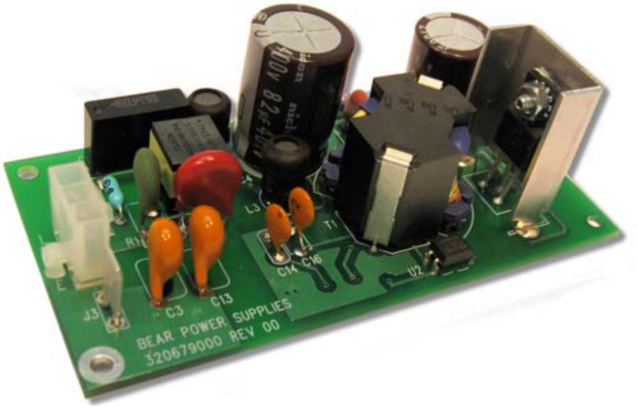
Highlights

- Power supplies for outdoor use, including smart grid applications, present special design challenges
- High and low temperature extremes stress components
- 6-kV, 3-kA surge protection is required

High-Temperature Challenges

The first design challenge is achieving a circuit with a long life at high operating temperatures. Outdoor electronic devices are typically housed in sealed enclosures for protection from the elements. Fans and vents are not options. The system designer may incorporate sun shields or passive phase change material (PCM) heat exchangers, but the temperatures within the enclosure will still get very high. Imagine the temperatures that the outside surface of an enclosure will reach after a few hours' exposure to the full summer sun on a 100° day. The temperature inside the enclosure will be even higher due to the heat generated by the electronics.

High temperatures shorten the lifetime of all components in a power supply. In our experience, utilities expect the power supplies to last at least 20 years, versus the five years typically expected of consumer and medical products. Achieving this long life at high temperatures requires conservative design techniques and careful attention to component selection and placement.



As part of a smart grid monitoring system to be mounted on a utility pole, this 30 W AC/DC converter from BEAR Power Supplies will deliver years of reliable operation under extreme temperatures and withstand high transient surges such as those caused by lightning.

First, you must specify extended temperature range components throughout the system. Consider the fine-print conditions such as required derating, airflow, or heat sink requirements. Also, understand that temperature ratings are simply the manufacturer's opinion of the maximum temperature you should run at and still expect a reasonable lifetime for the product. This may not be long enough for a utility application.

Capacitors require particular attention. A common power supply design technique is to use multiple capacitors for bulk storage. One solution is to use capacitors rated to +125°C rather than the more traditional +85°C or +105°C parts commonly used in consumer or industrial applications. These must be carefully selected, as different series from the same manufacturer have considerably different lifetimes.

Where possible, aluminum electrolytic capacitors should be avoided as they have extremely short lifetimes at higher temperatures, i.e., every 10°C increase in internal temperature halves the lifetime *(figure 1)*. Note the actual operating temperature experienced by the capacitor depends not only on ambient temperature, but also on ripple current (both frequency and amplitude), material thermal resistance, surface area of the can, and proximity to other heat sources on the board.

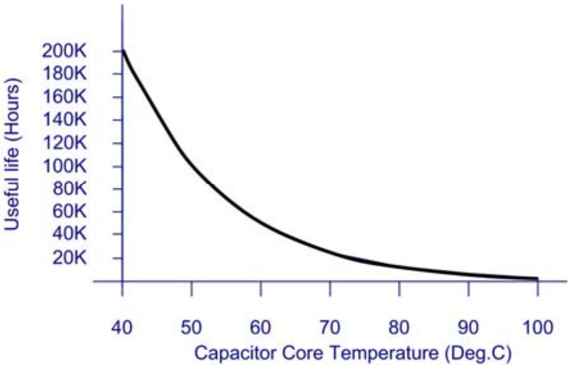


Figure 1: Electrolytic capacitor lifetime decreases with increasing temperature (standard long-life capacitor 046RSL from Vishay BCcomponents).

Low-Temperature Concerns

Outdoor systems must be able to operate reliably down to -40°C. This extreme cold can be nearly as big a design challenge as extreme heat.

For example, the capacitance of electrolytic and ceramic capacitors drops with decreasing temperatures *(figure 2)*. Don't assume a capacitor will work at temperatures lower than the spec as the dielectric in many capacitors is subject to freezing. Look for low-temperature rated parts, which have special dielectric chemistries.

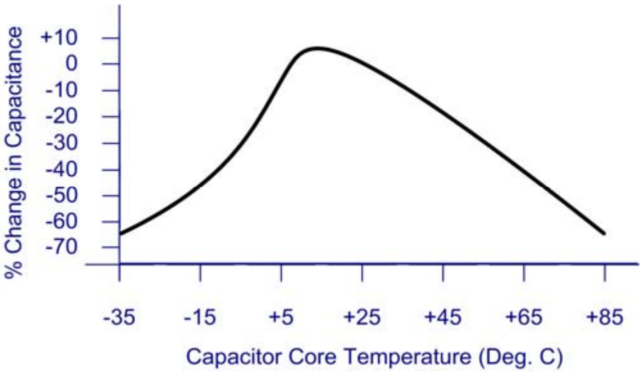


Figure 2: The capacitance of both electrolytic and ceramic capacitors drops with decreasing temperatures. The graph shows percent change in capacitance with temperature for a general-purpose class 2 ceramic capacitor (Y5V dielectric).

Your circuit design must take into account the actual capacitance at both ends of the expected temperature range. You must also factor in the increase in effective series resistance (ESR) of electrolytic capacitors as the temperature drops. The ESR value at a reading of -40°C may be ten times greater than at room temperature. This can limit the power output, increase noise and ripple, and reduce system performance.

In addition, wide operating temperature ranges mean that the designer must be aware of the thermal expansion coefficients of each component and the circuit board. Mismatches can lead to fatigue failure of the solder joints, which is fairly easily detected through testing. More subtle and harder to detect is component failure caused by stresses on the component pins, which can be transferred through the package and cause the die to lift.

The Threat of High Transients

Power supplies for outdoor equipment require special design techniques to protect the equipment from very high transients on the input line. These transients apply both line-to-line and line-to-earth and include repeated lightning strikes close to the equipment.

One standard in the industry requires the electronics be able to withstand a 6-kV, 3-kA surge with 1.2-/50-µs and 8-/20-µs rise/duration pulses, respectively. What's more, the power supply must be able to withstand not one pulse, but thousands of pulses in close succession. The photo shows a failure from this type of testing for one smart grid equipment manufacturer *(figure 3)*.

Power supplies designed to withstand this type of surge require special protective circuits incorporating components such as gas discharge tubes, transient

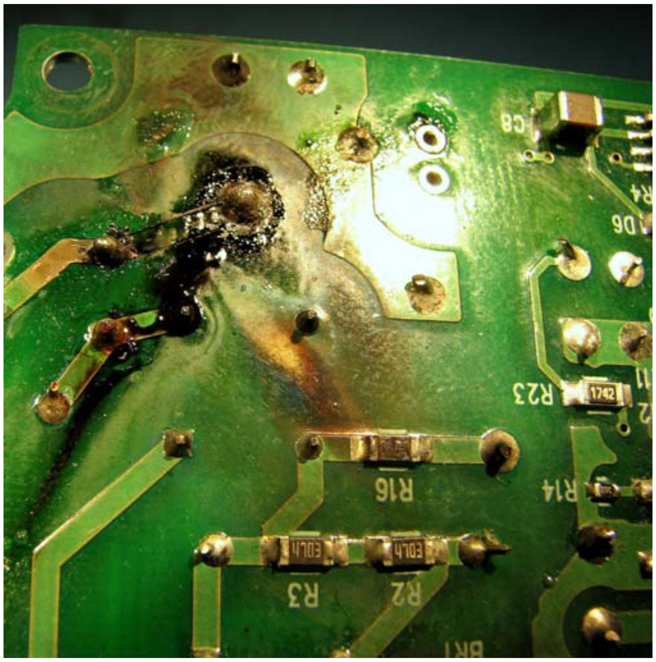


Figure 3: This power supply failed the 6000-volt/3000-ampere surge test after ~100 pulses.

voltage suppression diodes, and metal oxide varistors (MOVs) *(figure 4)*. Many design engineers aren't especially familiar with selecting and using these devices. It takes a good deal of time and experience to fully understand the issues in component selection, circuit design, and board layout.

Finally, the only way to know for sure that the protective network works is to test it. If you plan to hire a testing lab, be sure to factor in the time and cost of testing multiple revisions of the board. Alternatively, you can purchase a test fixture for tens of thousands of dollars, or build your own if you have the requisite knowledge as well as the equipment to verify 6-kV, 3-kA waveforms.

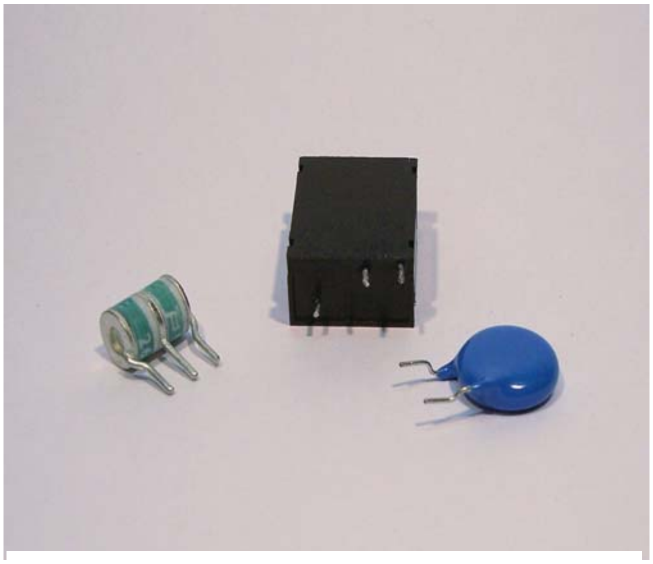


Figure 4: Surge protection devices include gas discharge tubes, transorbs and MOVs.

Make versus Purchase

Design engineers are not likely to find a commercial, off-the-shelf power supply that's right for their outdoor smart grid equipment. This leaves the choice of whether to buy a custom power supply or design it yourself.

As with most highly specialized tasks, you will generally save time and money by outsourcing this design task to a specialist. Even the most skilled design engineer who designs only one or two power supplies a year will not have the skills, experience, and resources of an engineer who designs power supplies every day. The specialist will also have better access to the necessary tools including frequency response analyzers, electronic loads, thermal simulation tools, electrical safety testing equipment, and lightning surge test fixtures.

When outsourcing, it is important to choose a company with experience in commercial and industrial power supply design, which is different than power supply design for consumer products. It is also a good idea to work with a firm that has both design and manufacturing engineering in the same facility. This gives the design engineers a more intimate knowledge of manufacturability and ready access to production facilities for faster prototype turns.

Finally, be prepared to share your system design plans with your power supply design team. Providing a more complete picture of your requirements beyond the specifications alone ensures that the power supply design team can not only meet your requirements, but also offer suggestions to improve system performance or reduce costs.

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