

Reliability of Switchmode Power Conversion Versus Legacy Technologies

MicroGenius 2 offers even better field observed MTBF than the already super-reliable NRG.

Operating at high frequency, switchmode power converters outperforms line frequency (50 or 60 Hz) power conversion topologies such as SCR and controlled ferroresonant in nearly every way. Switchmode technology delivers advantages in dynamic response, smoothness of DC output, size, weight, noise, energy efficiency, cost, and standards compliance.

Because they employ a larger number of electronic components than their line frequency counterparts, however, switchmode power supplies and battery chargers have historically been perceived as inherently less reliable. Moreover, because their power semiconductors are located upstream of the converter's power transformer, switchmode converters don't enjoy the inherent electrical transient protection afforded by large iron-core transformers located upstream of power devices in line frequency topologies.

This paper compares SENS' experience with actual field-observed failure rates of both line frequency and switchmode designs.

Observed field failure rate comparison: SCR vs. switchmode battery chargers in the same application

SENS introduced its NRG family battery chargers to the genset market in 2002. Employing a simple SCR (silicon-controlled rectifier) powertrain and all-analog controls, NRG was specifically designed to deliver high reliability and long life. SENS' NRG succeeded in these goals and has become highly regarded by customers for its durability.

In late 2016 SENS introduced its MicroGenius 2 charger that features power-factor corrected switchmode power conversion. One of the markets MicroGenius 2 addresses is genset starting, like the NRG. Although MicroGenius 2 handily outperforms NRG and all similar chargers -- charging performance, features, size & weight, efficiency -- when we began development, we were concerned that the significant additional complexity that enables its high performance might compromise reliability. We therefore devoted a large portion of the development effort to ensuring reliable operation. Here's how MicroGenius 2 stacks up to the NRG:

SENS measures and records the rate of field failure of all its products. We compared the failure rates of the first ~ 6,000 NRG and MicroGenius 2 chargers manufactured and found the following failure rates:

	NRG (SCR)	MicroGenius 2 (switchmode)
Failures due to electrical transient	1.66/10,000	1.64/10,000
Field-observed MTBF	1.4 million hours	1.1 million hours
Observed MTBF: hardware	1.4 million hours	2.1 million hours

The results validated our design objectives. The data confirmed that:

1. Vulnerability of the switchmode MicroGenius 2 design to lightning damage was *about the same as the more inherently robust SCR design*
2. Field-observed hardware failure rate of the switchmode MicroGenius 2 design was 50% better than the much simpler SCR powertrain used in the NRG charger.

This second finding indicates that, once the initial software bugs were ironed out, MicroGenius 2 delivers even more reliable performance than the already super-reliable NRG.

How does MicroGenius achieve the same low rate of failure from electrical transients as NRG?

In line frequency converters, designers exploit a beneficial property of the large 50 or 60 Hz isolation transformer by locating power semiconductors on the secondary side, electrically isolated from the AC source. Transformers operating at these frequencies function as low-pass filters, meaning that they minimize transmission of high frequency voltage transients typical of lightning strikes while allowing power transfer.

In contrast, switchmode designs do not employ 50-60 Hz transformers ahead of power semiconductors. This means that switchmode converters don't natively have the protection afforded by large transformers. In MicroGenius 2, SENS mitigated this risk by strategically locating gas discharge tubes, metal oxide varistors (MOVs) and surge clamping diodes. Together, these devices work to block or redirect transient energies around vulnerable electronic switches and other devices.

How does MicroGenius achieve 50% better field observed MTBF than NRG?

The "prime directive" of electronics reliability is preventing overstress of components, so that voltages, currents and temperatures of devices never exceed published ratings. One of the most powerful processes to ensure that components remain within their published stress limits is a design technique called "worst-case analysis". Worst-case analysis evaluates stress levels on all components when "worst-case" conditions are imposed upon them. The design team must solve all overstress conditions prior to release for manufacture.

Some designers continue to shake down prototype designs by abuse testing under the obvious stressful conditions of high heat and full power. Worst-case analysis, in contrast, employs engineering rigor to discover the points of the operating envelope where actual worst-case stresses occur. Sometimes, the worst-case condition is counterintuitive. For example, voltage stress on some boost converter switching FETs occurs at no load (when the FET is operating in hiccup mode) and cold temperature (when the FET's voltage rating de-rates to less than the device's room-temperature voltage rating.)

Worst-case analysis is just one of many tools SENS employs to achieve high reliability in its power converters. Many man-years of engineering and design time were invested in the MicroGenius 2 platform. Design engineering expertise included electrical, mechanical, thermal, firmware, software and production engineering.

Designing high reliability power electronics demands three elements: highly skilled design engineers, lots of hard work, and faithful application of disciplined design processes and reviews. Our adherence to this approach has enabled us to create – in the MicroGenius 2 – a product with not only state-of-the-art features, but also industry-leading reliability.