ABB solar inverters

Application note
MICRO inverter reliability

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Target audience and document scope

This document is written for installers, homeowners with photovoltaic (PV) systems, and others with an interest in reliability of smaller PV systems. It describes some of the engineering behind electronic equipment reliability and its applications to ABB's MICRO photovoltaic inverters.

Introduction

This application note addresses the following topics:

- In general, what makes any given piece of electronic equipment reliable?
- How does reliability apply to PV inverters?
- What are the unique reliability requirements for a microinverter?
- How is reliability designed into the ABB MICRO inverter system?
- How was the ABB MICRO system design confirmed and tested?
- How does manufacturing affect electronic equipment reliability?

Classes of photovoltaic inverters

PV inverters take the DC voltage generated by PV modules (also called "solar panels") and convert it to AC voltage usable by the electrical grid. Inverters are available with a variety of input and output voltages since those needs vary considerably from one installation to the next.

Panel inverters are designed to work with one PV module at a time, making them suitable for residential and small business applications, especially those with PV modules that don't all have the same shading.

One benefit is that if one PV module is shaded or fails, or if there's a wiring problem, only the 250-300 watts from that single PV module-microinverter pair is impacted, while the rest of the system is unaffected.

String inverters have higher input voltages, accepting voltage from "strings" of PV panels wired in series so their voltages accumulate. String inverter power ratings are roughly 2-30kW, they typically are high efficient, and are more cost-effective for large systems where a number of microinverters would be unwieldy. For even larger systems, multiple string inverters may be wired in parallel. ABB's offerings include the UNO, TRIO, and PVI product lines.

Central inverters have even higher power ratings, starting around 200kW, for large installations where the cost and wiring of many string inverters become impractical. Central inverters are suitable for large commercial and utility-level PV systems. ABB's central inverters are the PVI-Central and ULTRA series.

Reliability of electronic components in general

Electronic components such as transistors, diodes, resistors and capacitors are, in general, noticeably more reliable than moving parts such as fans and switches. Components have life expectancies which follow a "bathtub" curve (Figure 1), though the shape of the "bathtub" varies somewhat for different classes of components. Moving parts have a steeper end-of-life profile.

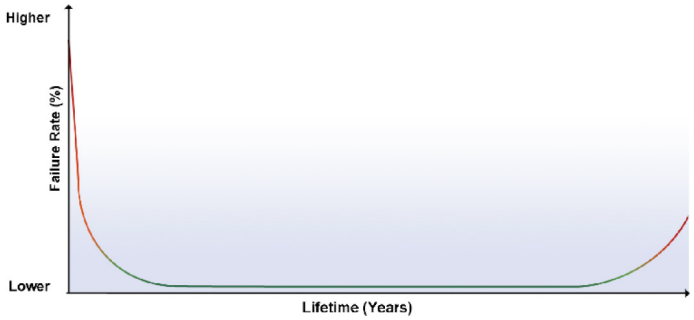

Figure 1 Approximate failure rates over time for electronic equipment

There will be some "infant mortality," which is one reason why some consumer electronics have short 1-3 month warranties. More expensive items usually have factory tests to help weed out those early failures. This is followed by a long operating life—very long, in fact, for well-designed electronic circuits—with very few real component failures. Eventually components are expected to "wear out," and moving parts wear out long before the electronics.

The duration of the low-failure rate operating life—which should be a number of years—depends on how much the electronics are stressed by factors such as high voltage, high current, radiation and especially heat. Electronic components' vulnerability to heat explains the fans found in computers and other appliances, and the metal fins seen on inverters and even on computer microprocessors. Heat generation and the ability to remove it limits how small and compact a piece of equipment can be made.

Design for a long, reliable operating life

Good product design requires a thorough understanding of actual operating environments. For example, a desktop computer sits indoors, and doesn't need to be portable. However, a laptop must survive continually being plugged, unplugged, and moved around, yet be lightweight, small and run for a reasonable length with a reasonably small and affordable battery.

More modern circuitry can limit voltage spikes and current surges on components, but designing it requires experience. Efficiency is important, not only to reduce energy consumption, but to reduce self-heating. Since heat is particularly hard on electronic components, design for a hot environment requires thought, planning and experience.

Mechanical packaging is critical for wicking away heat, protecting parts from dirt and humidity, and making installation uncomplicated

ABB MICRO inverter's design for reliability

ABB has considerable experience in inverter design, with over 10 gigawatts' worth of inverters installed and operating worldwide, from 250-watt, single-PV panel microinverters, to 1.5 megawatt utility-scale high voltage inverters. This experience is critical in comprehending real-world operating conditions, what electronic components and hardware are available in the marketplace and where to purchase them, in understanding the tests that are required to confirm inverters will perform well after leaving the factory, and in understanding how to build, ship and install inverters.

While a microinverter is functionally a scaled-down string inverter, its reliability requirements are somewhat different due to its installation location. A microinverter must work outdoors with limited airflow in the heat of a rooftop, in a hot climate, and survive rain, ice, snow, thunderstorms and the salty air near an ocean. This operation must be reliable for many years, especially since these rooftop microinverters are beneath PV panels and not readily accessible for maintenance. The inverters must be robust enough to handle any vibration or drops encountered during shipping and installation.

It's not sufficient for only the inverter to be tough—its cabling and reporting system must also be easy to use and work equally as well. All these considerations went into the design of the ABB MICRO inverter. The following sections describe the design methodology and design confirmation tests performed by ABB to ensure the product's reliability.

ABB's circuit design

ABB MICRO inverters have best-in-class efficiency. This reduces internally-generated heat which must otherwise be removed, reduces the total number of components required and enables all the components inside the ABB MICRO inverter to go on a single printed circuit board. The reduced component count results in lower defects and higher reliability.

Internally-generated electronic noise is a common by-product of inverter circuits. The traditional way to handle this is for a circuit design engineer to add more components and circuit board space to filter out the noise. ABB's inverter circuitry employs advanced techniques to drastically reduce those internal noise-generating voltage spikes. This circuit design reduces stress on internal components and results in longer inverter life.

Electronic component selection

Most electronic equipment has aluminum electrolytic capacitors inside; these are widely used in power electronics, are economical, and are familiar and widely available, but they are quite susceptible to performance degradation from heat. Avoiding them significantly increases long-term reliability in high temperature environments. ABB MICRO inverters only utilize thin film capacitors, which are far better suited for high reliability applications.

Other electronic components were carefully selected to avoid operation close to their rated voltage, current and temperature limits, even during midday startup and shutdown, or during voltage surges, dips, or sudden changes in current due to shading, grid failures or dropouts.

Thermal considerations and packaging

Considerations for the design of the MICRO inverter chassis and packaging included ease of installation, ability to wick out heat, resistance to corrosion, temperature swings and shipping vibration, safety, and avoiding the need for fans.

If a piece of electronic equipment has fans, then its reliability is quite dependent on those fans, and they're best monitored continuously and replaced before they fail. ABB's MICRO inverters are designed without fans or other moving parts to avoid the need for such maintenance.

Analysis of the design for reliability

A mean time between failure (MTBF) analysis gives a type of estimate for the reliability of any product. Due to the many assumptions made for MTBF calculations, it is often difficult to judge the actual reliability of a product in an absolute sense. However, given like products and similar assumptions, the MTBF can offer key insight into the reliability of a product relative to another similar product.

The MTBF calculation can also be useful during the design phase to help flag components which might be working closer than desired to their voltage, current and/or power ratings, so the component of that section of circuitry can be changed.

The ABB MICRO's MTBF, according to an industry calculation standard, Telcordia Issue 1 (using independent third party Relex software, PTC Corp.), is 1.2 million hours.

Design confirmation and testing

Merely designing an efficient product, simulating its waveforms, and examining its laboratory behavior is simply not sufficient for confirming its design is robust. A number of "torture" tests should be employed during design of higher-reliability products to help identify any weaknesses, and the ABB MICRO inverter completed a number of such tests during its design phase.

The ABB MICRO design was subjected to a number of extra reliability tests not always given to common consumer products. All tests were performed repeatedly, on a number of product samples, over several days or even weeks (depending on the test). The design was released to production only after all tests were passed.

These reliability tests included:

- **Accelerated life testing.** A number of product samples were run at high temperatures for a number of weeks in an attempt to simulate its lifetime. Many years of studies in this area have resulted in equations which suggest how much extra heat, how many test samples, and for how long, to have confidence in the MTBF calculation. The accelerated life test was concluded only after the entire sample of inverters, monitoring system and cabling successfully passed the test.
- **Overload at elevated temperatures.** These tests demonstrate design margins beyond the specified operating voltage limits.
- **High temperature and low temperature.** These also demonstrate design margins beyond the operating limits.
- **Thermal cycling.** These tests subject the equipment to fast hot/cold cycles, both to help determine design margins and to aggravate and identify any weaknesses in the circuit boards.
- **Humidity, both hot and cold.** These test pressure changes and environmental effects on the system and the metal ABB MICRO inverter chassis.
- **Three-axis vibration.** These help confirm the inverter is sturdy for transportation by air, sea or land.
- **Corrosion tests.** These verify the durability of the metal chassis.

Testing in real-world conditions

A piece of electronic equipment which works fine in a lab and factory will inevitably see different usage conditions in its real world. Maybe a cell phone rides around in a pocket, gets sat on, and is subjected to mechanical stress not quite imagined by the designers. Perhaps a product has different on-off cycles in real use than envisioned. Perhaps customers come up with new ways to plug in cables, drop the items, etc. Testing in a "real world" environment and analysis of the circuits under such conditions is essential for reliability. For field reliability tests, a microinverter must be in an actual PV system, connected to PV modules and to a functioning electrical grid.

Prior to product release, ABB MICRO inverters were field-tested for several months, with a variety of solar panels, in several countries, with various voltages and electrical grids, with climates ranging from cold and dry, to hot and dry, to warm and humid. The systems were monitored at all times.

Manufacturing

The best product design isn't useful if it's too complicated to reliably manufacture. Manufacturing of electronic equipment is not trivial—components must be of high quality, from qualified suppliers, carefully inserted in the proper locations on circuit boards. Solder paste must be fresh, circuits boards must be handled carefully, not dropped nor subjected to electrostatic discharge, and solder joints must be inspected. It is essential that a factory manager understand the procedures to keep all processes under control. To ensure high reliability, quality control must be implemented at various levels in a factory, from purchasing components to the manufacturing processes. One of the ways to achieve this is to have full control over the different departments involved with the ABB MICROS. ABB MICRO inverter production takes place in factories fully owned by ABB—manufacturing processes, testing procedures and raw material are under ABB's full control.

ABB's MICRO products are given a complete set of factory tests, including automatic optical inspection of printed circuit boards, insulation and functional and burn-in tests. Modern statistical methods are employed to continually monitor factory processes to ensure high quality end products. Results of ongoing reliability tests and immediate analyses of any production failures are fed back to design engineers for product improvement.

Warranty

A failure of any component, whether it is the inverter, cables or monitoring solution, determines the overall reliability of the system. Therefore, ABB backs all the system components, including the MICRO inverter, all cables, accessories and monitoring hardware with a standard 10-year warranty. With ABB's technical support hotline, global field service network and training resources, customers are assured the highest level of support for all ABB products.

Summary

Creating a reliable product requires a solid understanding of the application, engineering excellence from concept to manufacturing, and extensive field testing. For the ABB MICRO inverter, ABB aims to achieve this excellence not just through high quality design, manufacturing and extensive testing, but also through our worldwide technical support and training resources. The MICRO inverter provides excellent performance, maximum reliability, and long-term satisfaction.

For more information please contact:
www.abb.com/solarinverters

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