

AP Series



**EXTREME
RELIABILITY
IN POWER
OPTIMIZATION**



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TECHNICAL BRIEF

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Power Electronics Increase ROI

The success of a PV installation is largely gauged by how quickly it can reach return on investment and how much it can reduce energy costs. PV modules have made significant advances in the past thirty years, but it is the rise of solar power optimization electronics that are bringing the most dramatic developments to the industry. Solar power optimization electronics shorten return on investment and diversify suitable installation locations.

Power optimization electronics, such as DC to DC converters and micro-inverters, increase total energy harvest by reducing the impacts of shading, panel mismatch, and other obstructions to power generation. Azuray Technologies' DC to DC Converters harvest up to 99.2% of available power from shaded panels. Power optimized electronics result in a faster return on investment for system owners because power that would otherwise have been lost is recovered and used. This accelerated ROI depends largely on how robust and reliable the array's power electronics are. A typical solar array is expected to function for 20-25 years without requiring unscheduled maintenance. If power electronics are unreliable and fail to operate effectively, unforeseen maintenance and repair costs can reduce the systems overall energy production and delay ROI.

In general terms, reliability refers to the ability to perform and maintain full function in routine conditions as well as in hostile or unexpected circumstances. Depending on the manufacturer, this broad definition can hold a variety of interpretations.

At Azuray Technologies we design our AP product line to perform at extreme levels of reliability. Our MPPT DC to DC converters have an Annualized Mission Availability of .9999998 or "six nines with an 8". This exceptional system availability is due to advanced and comprehensive design and reliability engineering procedures employed by Azuray Technologies engineers. We base our procedures on an extensive body of reliability and derating knowledge developed by the US Telecommunications and Military and Aerospace (Mil/Aero) industries. Azuray uses exhaustive HALT testing and rigorous component selection to create products that substantially exceed design requirements for derating and environmental conditions.

The following is an overview of Azuray's Extreme Reliability methodology. It shows why customers can truly depend on Azuray products to perform as expected for the target 25 year life of a solar array.

Component Selection

A key element of Azuray's Extreme Reliability methodology is rigorous component selection. In order to attain maximum reliability, it is essential to select components that have the capability to support long mission times (25+ years). If a single component has insufficient performance *or* contains technologies known to have long term reliability risks, that component will limit, or reduce, the overall reliability of the product to that of the lowest performing element. As such, Azuray Technologies uses only Automotive/Military/Industrial grade components. Azuray believes that this class of component is required to withstand the extreme demands of solar power generation. The company excludes +85°C rated components in mission critical circuits as well as components known to put a product's long term reliability at risk, such as electrolytic capacitors (more on page 6).

Thermal Acceleration of Failure Rates

An accepted guideline for thermal acceleration of failure rate states that the failure rate for a given component doubles for every 10 degrees of temperature increase.^{i,ii} In other words, for every 10 degrees of operational rating in a given environment, the failure rate for a given part at a specific temperature is cut in half.

For example, a +105°C rated part will have four times the reliability of a +85°C rated part at a given temperature. Likewise, a +125°C rated part will have sixteen times the reliability of a +85°C rated part.

Employing a single +85°C part limits an entire product's ability to attain an extreme reliability profile. Power optimization modules, mounted on the backs of panels commonly experience temperatures that exceed +85°C. This significantly overstresses the power optimization components and puts the PV system at risk of failure. This is because component failure mechanisms are highly accelerated by temperature. Thus, a component's temperature rating fundamentally affects the failure of not only a particular component but the entire product.

Surprisingly many power optimization manufacturers employ +85°C rated parts in their DC to DC converters and micro-inverters. Azuray Technologies believes the use of +85°C rated parts puts the long term reliability of solar power conversion devices at unacceptable risk. Thus, +85°C rated components are excluded from the Azuray AP product line.

Automotive/Military Grade Components

In light of the thermal acceleration of failures in +85°C rated components listed above, Azuray Technologies uses only Industrial, Automotive (SAE) or Military/Aerospace

grade components in its AP product line. This is a step beyond competing products in the power optimization sector, where commercial grade components (rated to +85°C) are commonly used.

In contrast to other manufacturers in the industry, Azuray uses only the most rugged, highest capability components available. In the AP product line, every component is rated to 105°C or higher. Not a single +85°C rated part is used in the AP Product line. Taking advantage of the highest capability parts available provides Azuray with lower stress ratios on components compared to its competitors. This directly relates to lower lifetime failure rates at the product level and the product's durability and safety in stressful conditions.

Technology Components Excluded from Azuray Products

To ensure the extreme reliability of its AP product line, Azuray excludes certain components that are acknowledged by the company, industry manufacturers and reliability experts to put at risk high product reliability and long mission time. These exclusions in Azuray's AP product line include, but are not limited to:

- Electrolytic capacitorsⁱⁱⁱ

- Tantalum capacitors^{iv}

- Large multilayer ceramic capacitors

- Optocouplers

- Powdered iron core inductors with organic binders^v

- Any component parts rated +85°C or lower

By eliminating these and other components/technologies, Azuray Technologies provides an inherently more robust, long term solution for the solar industry and its power optimization needs. By designing for extreme long life reliability and ultra low failure rates Azuray delivers the lowest total life cycle cost of ownership.

Component Derating

In the 1960's, NASA and military suppliers pioneered the use of component derating guidelines as one way to enhance the reliability of systems. Azuray agrees with experts in the field that employing Department of Defense based derating in circuit construction makes them more reliable as well as improves circuit performance.^{vi} Derating guidelines are not requirements within industry and are obviously not implemented

when +85C components are being used in solar power applications with measured field conditions that meet or exceed that rating.

Azuray is committed to following strict derating guidelines as provided by the Reliability Information Analysis Center (RIAC), a US Department of Defense Technical Center. Azuray designs meet or exceed the Mil/Aero level of component stress derating recommended for mission critical long life applications.

In addition, the company has identified other potential risks to attaining a fault free 25-year life for its products. Therefore, in many cases we have added additional derating for specific components. These extra steps result in a more robust and durable AP product line, which in turn contributes to the product line's overall extreme reliability, long life and lowest lifetime cost of ownership to our customers.

Reliability Modeling

Another critical component of the extreme reliability of Azuray's AP product line is the company's complex and highly accurate reliability models. Azuray subscribes to the Telcordia SR332 failure rate database which provides the very latest information on actual field failure rates for components. This information is used to build precise models of Azuray products and to run hundreds of "what if" scenarios. These scenarios precisely model actual mission profiles for specific locations worldwide and identify the highest contributors to product failure rates. It is this modeling and analysis that demonstrated devices containing electrolytic, tantalum and large multilayer ceramic capacitors would severely limit a products ability to reach the target reliability of a 25 year failure free life.

Reliability testing at Azuray Technologies includes a wide range of tests including Highly Accelerated Life Test (HALT), environmental tests and reliability demonstration testing. Coupled with these tests is a grounded philosophy that Annualized Failure Rate is a more informative indication of reliability than Mean Time Between Failure (MTBF).

Other power optimization electronics manufacturers may publish their highest Mean Time Between Failure (MTBF) rate as a way to establish a perception of reliability. However, from the perspective of Azuray Technologies, using this metric as a determination of reliability is disingenuous and misleading. By contrast, Azuray takes this predicted lifetime from a simulation (MTBF) and generates an Annualized Failure Rate to estimate the reliability over the useful life of the product based on actual measured field conditions (mission profiling).

Understanding Mean Time Between Failure (MTBF)

Throughout the electronics and power conversion industry the Mean Time Between Failure metric is widely misunderstood. People without experience in reliability engineering interpret the MTBF to be the “useful life of the product.” They think a product with a high MTBF rate will last longer than a similar product with a lower MTBF rate. This is not always the case since HOW the MTBF is generated determines not only the accuracy of the prediction but the validity.

An example of this misunderstanding would be if a product has a 5 million hour MTBF, people might think it should last over one hundred years. However, this is not what MTBF means. Instead, MTBF is an estimation of when 62 percent (the mean time to failure in a population) of the installed base will have failed. It is the mean of the distribution of failures. In other words, the MTBF indicates when more than half (62 percent) of the products in a given population will have failed. Stated another way, for any single product there is a 62% chance the product will have failed by the MTBF estimate. This is a poor measurement of what a customer should expect because it is not intuitive how to relate MTBF to actual failures in time.

This is not to say MTBF as a metric is invalid. It is very useful in determining the steady state failure rate and for making comparisons between two items (if those items use the exact same methodology and the same exact failure rate database). This allows an A/B comparison that provides information to determine which product has the best design reliability for the cost. Unfortunately not all manufacturers invest the time and expertise to develop highly accurate reliability predictions and instead simply generate a high MTBF number that on the surface seems to indicate high reliability.

It is essential to also understand that a calculated MTBF is a poor predictor of wear-out in a product. A high MTBF figure may accurately reflect a low failure rate during the normal operating portion of a product’s life but completely fail to indicate a wear-out failure mechanism from overstressed parts. It is not only possible but entirely likely that using 85°C parts in an application that exposes those parts to an 85°C environment (100% stress ratio) would have a high calculated MTBF. This will appear in actual application as a low steady state failure rate that rapidly increases due to wear-out well before the required 25 year useful life.

Field Data

Unfortunately, the panel level solar power electronics sector is so new and its technology so cutting edge that no manufacturer has had enough units in the field for a long enough period of time to collect meaningful long term reliability data. As such, Azuray Technologies employs rigorous reliability modeling and testing and stresses the

use of AFR over MTBF. We have seen manufacturers of solar power devices state multi-million hour accumulations of field data, but when one examines the data you find that the actual hours per unit deployed averages to less than one year in field per device. This is hardly acceptable data for demonstrating long term reliability since the data contains no information of failures occurring during the critical time period of out 10+ years. That data simply does not exist today.

Highly Accelerated Life Test (HALT)

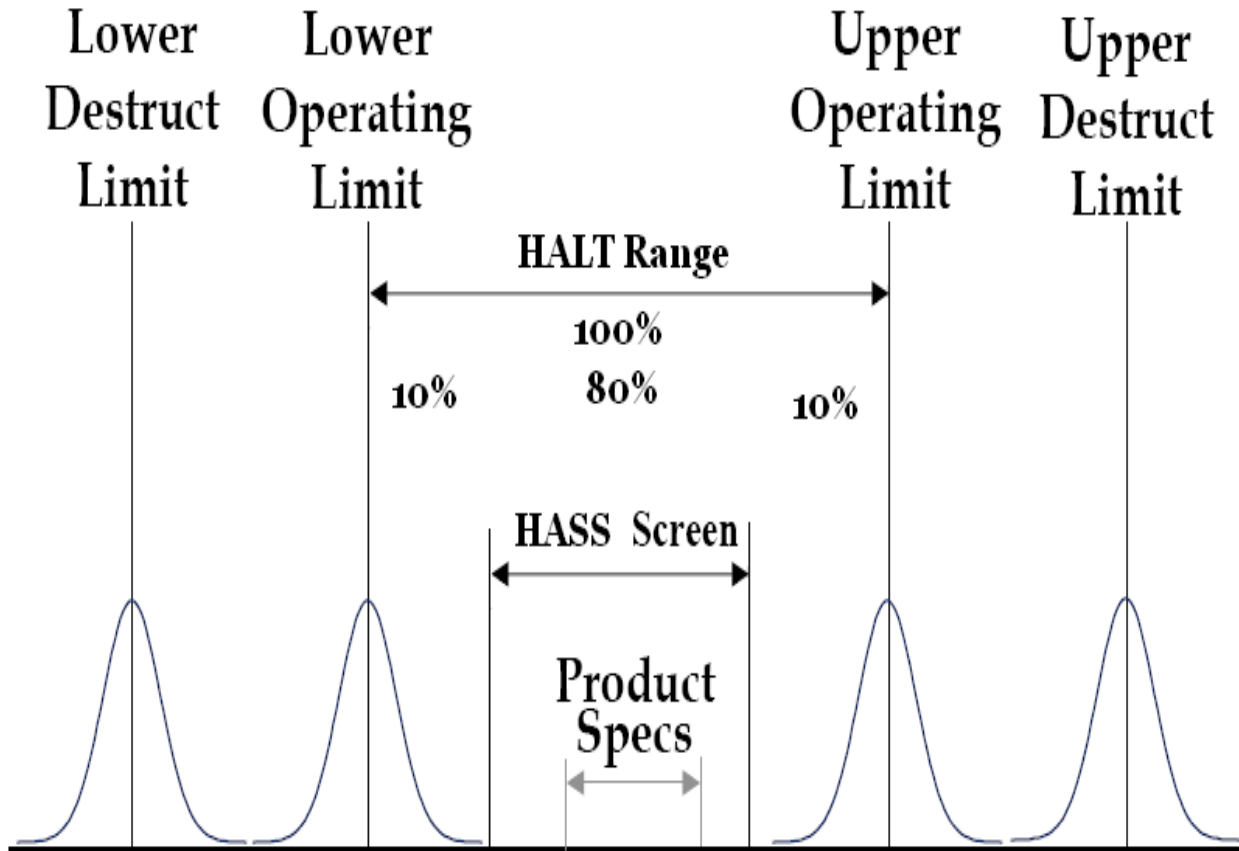
Another critical aspect of the extreme reliability of the AP product line is Azuray’s studious attention to margin. Margin is when a product is designed to handle stress above its operating environment. The higher the design margin the more robust the product will be. For example, if a product is specified to operate at 65°C but it breaks at 66°C, that product has very little if any margin. Compare that with a 65°C rated product that can operate to a temperature of 105°C. The implication of having extreme design margin due to component selection and aggressive derating can be significant!

The large design margins of Azuray products are the result of multiple HALT tests during product development. This process identifies the weakest elements in a design. Once identified, those elements are improved, replaced or corrected until the HALT testing is able to take an Azuray product to the fundamental limit of technology. Through its HALT tests, Azuray is able to show the AP product line has the capability to operate well beyond the specified range of operation. During the final HALT series, the AP300 reached the thermal/vibration limits of the test chambers before identifying the next order failure mechanism. This represents a significant design safety margin beyond the specified product operating limits. It also demonstrates that when properly executed HALT can be used to drive product design to the fundamental limit of technology and therefore its highest reliability potential.

Final HALT results for AP300:

Product	Upper operating limit	Upper destruct limit	Lower operating limit	Lower destruct limit	Vibration operating limit	Vibration destruct limit
Ap300	>+120°C	>+130°C	<-90°C	<-90°C	>50Grms	>50Grms

Stress/Strength Relationships:



The HALT range represents the inherent operating limits of the design. The wider the margin between product spec and HALT limit, the more robust the product is over time due to lower stress ratios between design strength and use environment.

Component Specs - In all cases component specs exceed product specs with additional margin

Environmental Test

In addition to HALT testing, complete environmental compliance testing is executed on all Azuray products. This includes but is not limited to: temperature, humidity, thermal shock, random vibration, swept sine vibration, operating shock, dust/contaminant intrusion, corrosive atmospheres, fungal growth, altitude, and transportation shake/shock.

Reliability Demonstration Testing

Azuray products also undergo long term testing in order to prove to a statistical certainty that the test population does not exceed the target failure rate. This typically consists of calculating the required test sample size and test duration to demonstrate that the target failure rate is not exceeded. The test is monitored daily, and any failures are removed and analyzed for root cause. A formal corrective action process is followed to ensure any product improvement opportunities are not missed.

Conclusion

Azuray Technologies employs the most advanced and comprehensive Design for Reliability methods in the industry. During the development process we drive the stress/strength relationships and therefore the design margin to the fundamental limits of technology. Our large margins ensure that the inherent strength of the design far exceeds the stress that the product experiences in the end-use environment. We employ derating guidelines developed and proven by other ultra long life and high reliability industries such as the automotive, military/aerospace and telecommunications industries. This level of innovation allows our product to have the highest performance envelope while avoiding known long term reliability risks at both the component and product levels.

This extreme level of reliability in Azuray Technologies products give our customers confidence that our products are robust and durable enough to last as long as the PV panels they serve. Having this confidence is pivotal to ensuring ROI calculations are accurate. When system owners and integrators feel assured an array will generate solar power to the utmost of its ability, regardless of shading mismatch and other obstructions, that confidence supports the financial models used to fund the array's installation. From the Azuray Technologies point of view, power optimization electronics employed to increase a system's energy harvest must be highly functional and extremely reliable to encourage their use in new and existing PV installations.

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