HiQ Solar TrueString Inverter –
An Architecture Designed for Reliability

The Weakest Link

The weakest element in the long-term reliability of most PV systems is the inverter. At the same time, all inverter manufacturers claim to be the most reliable. We looked at this and decided we wanted to do more than claim – our whole design philosophy was centered around making our TrueString Inverter the most reliable available.

Our background is different to many in the solar arena; we come from a test background, focused on high-speed telecommunications. Telecommunications has extremely high expectations for reliability and system availability. Some lessons we learned in this arena about reliable product design are:

- The more connectors involved in a product, the more likely it is to develop problems. **Connectors** are a significant **source of unreliability**
- The **more circuit boards** involved, the more faults develop
- Circuit boards with **many layers**, populated on two sides, and using ultra-small components all have a high rate of failure
- **Components** used close to their **maximum ratings** are more likely to fail. This includes voltage, power and temperature ratings
- **Electrolytic capacitors** tend to dry out over a period of a few years and fail
- The motors in **electric fans** tend to be a weakness, also

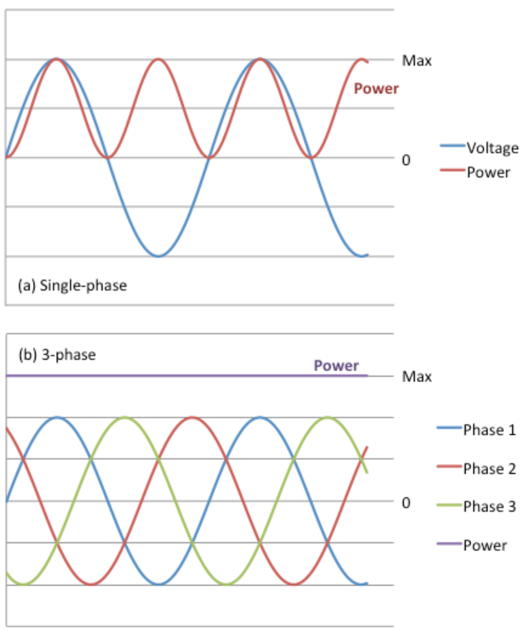
It was a surprise to us that many inverter companies seem unaware of some or all of these lessons. It is also surprising that many designs seem to be from the last century, with reliability issues that come along with this.

A More Sophisticated Approach

In the design of the HiQ Solar TrueString Inverter we have used a variety of approaches to maximize reliability, from the overall architecture through to the smallest details. Some of these are listed below.

3-phase Architecture

Inverters take the constant power from the sun in electrical form, and converts it to the AC required by the grid. Residential electrical systems are usually single phase in the US. The picture shows a single-phase voltage, and the consequent power delivery, which is like a sine wave. An inverter therefore has times when it can dump the power from the solar modules straight into the grid, and then times when the grid's ability to absorb it is zero. During these times the inverter has to buffer energy while it waits for the grid to be able to accept power again. This is one reason why many inverters have electrolytic capacitors in their design, to store the energy temporarily.



In contrast, the lower picture shows a 3-phase waveform set, with three separate sine wave voltages, each 120° phase shifted from the others. One useful aspect of such a system is that while any one voltage is dropping, others are rising, so when added together the net result is constant power delivery (purple line in the lower picture). From an inverter perspective this is huge – it means that the inverter can always be transferring power to one or more of the phases at any point in time, and so does not need to buffer significant energy. Thus, a properly designed 3-phase inverter does not need to use electrolytic capacitors to store energy if proper care is used in its design.

The TrueString Inverter is natively 3-phase and uses no electrolytic capacitors.

Rugged Design

The mechanical and electrical design uses the lessons we learned from telecommunications test:

1. The enclosures are **completely sealed**, allowing no dust or moisture to ingress. This contrasts with many string inverters that need air cooling, usually using electric fans – the TrueString Inverter contains no fans of any kind.

2. All components used in the TrueString Inverter are **automotive grade**, with an operating temperature range of -40 to +105°C.

3. The circuit **boards are single sided**. This matters because double sided boards solder one side, then flip and solder the other. Heating for the second side tends to disturb and possibly reflow the solder on the first side, leading to unreliability.

4. The **boards are 4-layer with no fine structures.** The consequence of this is that there is nothing cutting-edge or risky about their construction.

5. **We have one circuit board** in the inverter as can be seen from the photo. Multiple circuit boards in an enclosure tend to mean higher cost and more wires and connectors to come loose or break. Contrast this with most other inverters.

6. Internally the TrueString Inverter has **60+ sensors** that measure parameters minute by minute, many measuring multiple times per second. These include moisture detection, and also many temperature sensors. The data is processed by multiple on-board microprocessors. These measurements are compared with thousands of measurements that are taken in manufacturing test that are stored in our database. This allows us to make firmware updates that benefit from user data to optimize reliability for all units.

7. **Multiple temperature sensors** allow detection of gradients across the package. They also allow sensing of clipping – when the solar output from the PV array exceeds the capacity of the inverter. This behavior tends to happen for very short durations, and a minute of lost production in order to **increase system reliability** is frequently a good trade-off to make. Specification of a lower capacity inverter than the possible peak output of a panel array can result in a better ROI when peaks happen so rarely.

   Dangerous thermal behaviors can also be detected and managed to maximize reliability.

In addition to features listed above that aid the reliability of the TrueString Inverter, our product can also **aid the reliability of other system elements**.

8. **MPPT and monitoring per individual string** reduce the likelihood of individual modules under-performing without detection.

9. The TrueString Inverter is capable of **detecting arcing** in connectors and cables with higher sensitivity and fewer false-positives than other designs.

Conclusion

A track record in telecommunications test has allowed us to bring a unique perspective to inverter reliability.

We have units with customers that have been operating for more than 2 years in harsh environments. Examples are shown which were at a customer near Death Valley in heat, sandstorms and a water-spray. They function like new. Our architecture is desert-proven to be designed for the utmost reliability.