Balance-of-system components and new PV ecosystems

Testing and certification | Ensuring the safety, performance and durability of non-module components in a PV system is an ongoing challenge for the solar industry. Robert Puto of TÜV SÜD looks at the latest testing and certification programmes in place to help bring greater certainty to balance-of-system procurement

For those who like me believe in a carbon-free future, expecting a strong uptake of renewables is a safe assumption. We are going to see more residential, more commercial, more decentralised solar PV in years to come.

We have all been fascinated by the learning curve of the global PV industry over the last 10 years. The most remarkable result of that curve, as well as the most visible to most stakeholders, has been the relentless decline of PV module costs. With a lot of attention focused on their quality and price, we have gained solid knowledge to make informed decisions when it comes to selecting a suitable technology and a reliable vendor for our PV systems.

We can't say the same about balance-of-system components, which have not received the same attention, not until recently and for an obvious reason. For the purposes of this article, we define balance-of-system (BOS) as all components other than/beyond the PV module. Examples include wiring, inverters, mounting structures, combiner boxes, protective devices, switches, energy storage, etc.

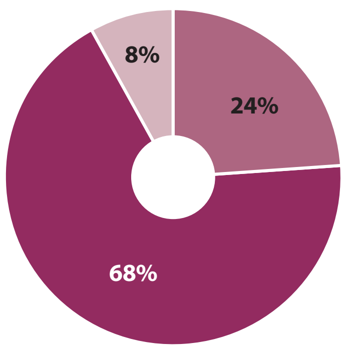


Figure 1. Contribution of the module, BOS and O&M costs to the LCOE of a typical solar system [1]

As prices hit new lows, modules have become a global commodity. This is not the case for BOS components. Their learning curve and cost decline have been much slower and over time their share of the CAPEX and overall LCOE of a PV installation has become dominant (see Figure 1).

It is also worth noting that the BOS landscape is more heterogenous than that of modules due to regional energy, environment and construction regulations.

Currently, BOS costs can make a difference in terms of capex. But a lower capex is not a guarantee for a shorter payback time and better ROI. Energy generation is. This explains the growing importance solar asset owners, EPCs and operators attach to the reliability of modules and BOS components.

Since day one, we in TÜV SÜD have developed reliability programmes alongside conventional IEC/EN/UL standards and certification schemes.

The approach is based on two types of criticalities: those detected, monitored and collected in the lab during testing, combined with those encountered during on-site tests and inspections of PV installations:

1) Reliability patterns during standard testing.
2) Reliability patterns occurring out in the field.

With more than 30GW+ of PV installations inspected worldwide, 1,000+ certificates issued for PV modules and 500+ for BOS components, we know where to focus on when it comes to reliability.

Failures continue to occur in PV installations and many of these are related to BOS components. Figure 3 shows some examples from the field of the consequences of failed components.

Let's have a closer look at services for the main BOS components.

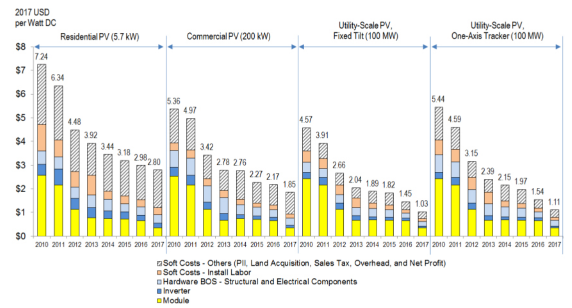
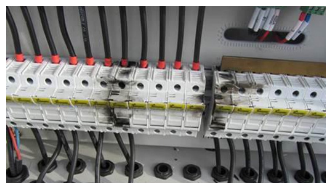


Figure 2. NREL PV system cost benchmark summary, 2010–2017 [2]

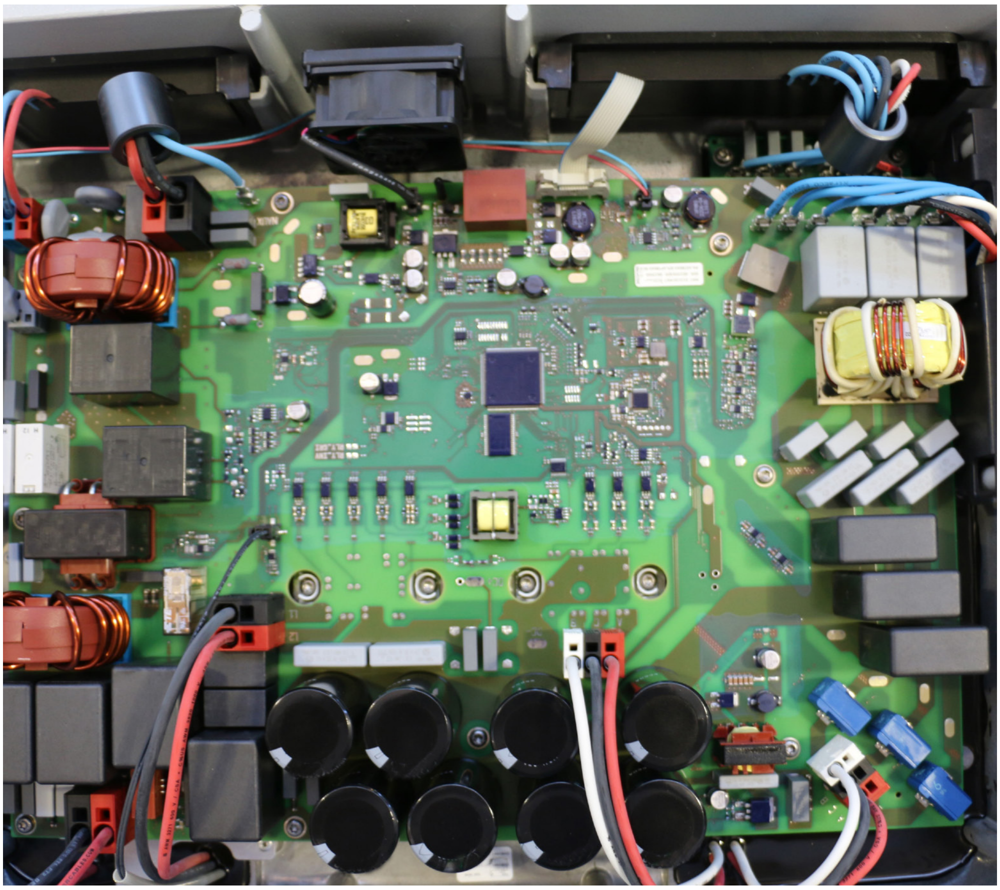
Figure 3. Examples from the field of BOS failures

IGBT inverter explosion/fire hazard caused by poor inverter quality and technical design.



Combiner box fire hazard caused by poor design and installation

Failure caused by poor mounting structure design



Credit: PVEL

Figure 4. Advances in inverter technology mean greater challenges from a testing point of view

Inverters

Inverters lie at the heart of all PV systems and as such are crucial to the reliability of the whole system.

Inverter technology has seen continuous advancement aiming to optimise system performance. An example is the adoption of 1,500V inverters as the result of PV module technology development towards 1,500V system voltage.

Higher system voltages require higher insulation strength for materials and components to withstand continuous normal system voltage and temporary abnormal voltages (eg. lightning surges). Consequently, increased clearance and creepage distances are required. This might imply either replacing old components with new ones or designing special solutions around existing components which can meet higher requirements.

As a matter of fact, achieving safety certification for 1,500V inverters to IEC 62109-1, -2 has resulted in a more challenging task than for 1,000V inverters. TÜV SÜD marks and certificates attest compliance of inverters with safety standards IEC 62109-1 and IEC 62109-2.

On the other hand, pressure to reduce costs has produced "collateral effects" in some markets. Chinese manufacturers, for example, have (understandably) decided to develop domestic alternatives to imported materials and components. Proving that new solutions offer the same level of safety and reliability is critical for asset owners. We at TÜV SÜD are addressing the matter through accelerated testing programmes based on IEC 62506 (Methods for product accelerated testing), combined with IEC 61709 (reliability of electrical components, failure rates and stress models).

TÜV SÜD reliability schemes are a very insightful tool for system designers and asset owners to evaluate and select the most suitable products. They enable informed decision making by reviewing and validating lifetime claims, warranty terms and maintenance contracts.

Cables

These are divided in two categories: PV and energy storage cables.

EN 50618:2014 and IEC 62930 are the optimal solutions for general purpose PV cables, in that by using them one can effectively evaluate UV resistance, electrical and mechanical properties, as well as the expected thermal life span.

Another interesting development is the increasing demand by EPCs for lightweight cables for use in specific applications. A TÜV SÜD programme will be soon released providing an evaluation method for aluminium conductor cables, covering both long- and short-term life spans.

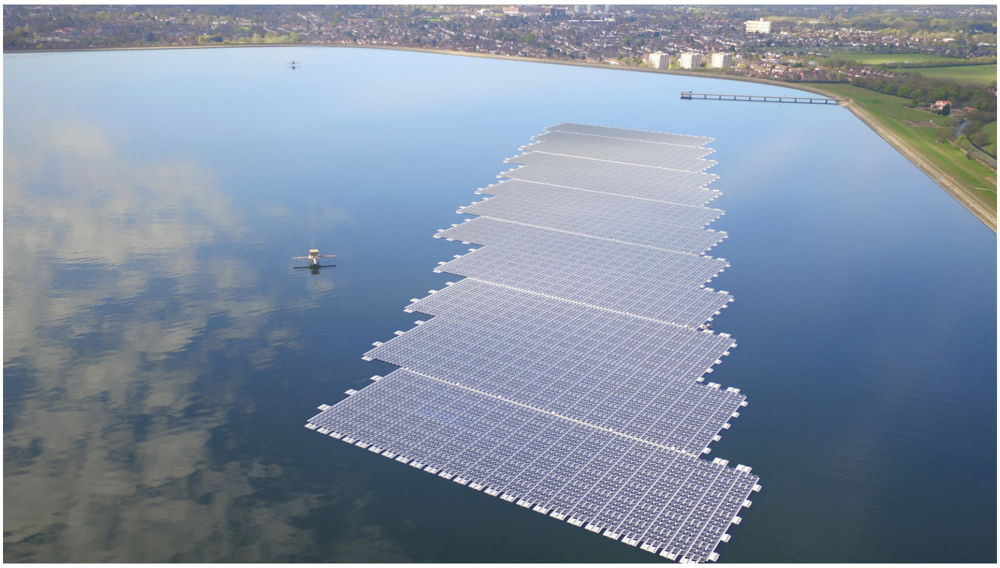
Cables used in floating PV need to be evaluated against specific requirements such as resistance to salt mist, water tightness, resistance to low temperatures, etc.

A specific TÜV SÜD programme will be available in early 2020 also for these cables.

As for cables used in energy storage applications, in absence of specific IEC standards, TÜV SÜD China has developed a joint testing and certification programme (PPP 58049A: 2019) with Quality Certification Center (CQC). The first joint certificate was issued in July 2019.

Figure 5. Cabling for storage is not yet governed by any specific IEC standards

Credit: Powin Energy



Credit: Lightsource BP

Figure 6. Floating solar installations involve a number of tricky engineering problems, necessitating a new set of standards

Mounting structures

Despite their small share in overall project costs, mounting systems have a significant influence on the long service life of PV modules. Only with a stable mounting structure over time can we expect optimal PV module power output. Environmental loads such as wind and snow, in combination with other specific climatic conditions (desert like, damp heat) need to be taken seriously.

PPP 59029 is a specific programme developed by TÜV SÜD in 2013, which provides a method to evaluate the environmental reliability to damp heat, thermal cycles and salt mist. The programme also uses finite element methodology (FEM) to simulate wind and snow loads per local regulations. After FEM simulation, an on-site load verification will be carried out.

Floating structures

As peaceful and relaxing as they look to the eye, floating solar installations hide tricky problems under the water. In 2019 the cumulative installed capacity of floating solar will exceed 1.2GW, with the prospect of doubling in just two years [3]. Due to low cost and mature industrial basis, polymeric floating body solutions are considered a very promising reality. However, currently there is no standard regulating polymeric floating bodies with a risk assessment behind it. In 2018, TÜV SÜD developed a specific programme, PPP 59073A – the world's first polymeric floating body certification scheme. It focuses on evaluating material properties (mechanical, burning characteristics, resistance to ageing), as well as product properties (buoyancy evaluation, tensile and shear strength of connection lug, fatigue test at design parameters and anti-wind capability).

Sun trackers

The prospect of adding an extra 10-20% energy yield on top is a tempting prospect, hence the increasing in use in large-scale PV plants. Being mainly a performance related element, TÜV SÜD developed the first performance evaluation method for solar trackers and issued the first IEC 62817 certificate in 2017. This is a design qualification standard defining methods to measure, calculate and evaluate parameters declared in specification sheets. Safety is not specifically covered by the standard, therefore a specific safety programme by TÜV SÜD is also available.

Protection devices

Several fire accidents in PV power plants have once again raised the alarm: root cause = DC arc fault. The US industry has been very responsive in tackling the issue by releasing UL 1699B: 2018, requiring all PV inverters sold in the US market to have a DC arc detection and interruption function.

IEC is currently working on a new standard (IEC 63027) to catch up on the matter.

TÜV SÜD keeps following the latest updates on the standard development, and this will be the future trend in testing and certification.

Credit: Smart Energy Council

Figure 7. Testing of smaller scale renewable energy storage systems covers critical safety and performance aspects

Energy storage systems

Given the intermittent nature of solar and wind energy generation, energy storage systems (ESS) have become the latest, extremely valuable entry of BOS components. They add value on multiple levels. By storing excess electricity and using it during times of peak demand they act as a buffer contributing to a more stable power grid. They are also the solution to the problem of power reliability in microgrid systems.

However, ESS technology maturity is yet to be achieved. Recent accidents due to battery fires, explosions and system mismatch show serious vulnerabilities linked to faults in batteries, battery management systems (BMS) electronics, power converters, etc.

While the industry actively invests in new solutions, the development of relevant technical standards is still lagging behind. With our extensive experience in solar/wind applications, and a worldwide network of battery laboratories, we have developed comprehensive testing schemes addressing the critical safety and performance aspects of residential, commercial/industrial and utility-scale energy storage systems:

1) Renewable energy storage systems – small and medium-size applications (residential, commercial, industrial). Testing & certification programme PPP 59034A: 2014. Covers:

- Battery/inverter safety, functional safety, EMC, global grid code compliance, emergency/stand-alone output quality, etc.

2) Utility-scale applications with PV/Wind. Testing programme PPP 59044A: 2015. Covers:

- Battery/converter safety, functional safety, EMC, round-trip efficiency, life endurance, walk-in system protection and safety, fire protection, electrical

installation electrical codes, global grid compliance, etc.
- On-site installation inspection and Final Acceptance Tests.

Industrial cyber security

Last, but not least. "Industrial IoT" is not a buzzword anymore; "smart energy" is the reality of interconnected energy assets exchanging data and interacting with each other to increase flexibility to changing conditions, enhance efficiency and maximise energy output.

The benefits offered by the digital transformation can be fully exploited only if they are risk-free. New hazards for people, property and environment need to be identified, assessed and mitigated. Given the critical nature of energy assets involved, achieving so-called "grid resilience" implies guaranteeing both "physical safety" and "cyber security".

The "secure-by-design" concept underlying IEC 62443 is the approach TÜV SÜD has adopted and recommends to address cyber security of commercial and utility-scale systems. Given the new nature of cyber risks, we are offering tailored training packages for product suppliers, system designers and asset owners. By sharing knowledge on cyber risk assessment, threat modelling and vulnerability testing, we are ready to engage together in a journey that starts with raising awareness, continues with gap analysis, implementation measures, evaluation and validation, and finally evolves in certification.

In summary, BOS components do make a difference, in terms of both CAPEX and overall system performance. Investors, asset owners, system designers and operators must pay closer attention to the criteria used in selecting their suppliers, keeping in mind that the real value of BOS components is a compromise between price and reliability. Overlooking safety and performance aspects can produce direct financial impact.

Standard testing and certification are necessary, but not sufficient. Specific applications, installation conditions demand deeper insight into reliability.

An example is the need for differentiated requirements for lightweight cables in floating PV applications. Likewise, desert installations, or energy storage systems, pose different challenges to cables and supporting structures. Another example is the wider adoption of bifacial modules, which will bring about an increase in the use of sun trackers.

Credit: Greensmith Energy

Figure 8. Testing of utility-scale storage applications covers battery safety through to on-site inspections

Looking ahead, two scenarios will shape the future of the sector: further decentralisation and smart energy solutions.

As a result, energy storage systems will be very soon the new, very important BOS entry. They require a new kind of knowledge that combines batteries, power converters, DC-AC coupling and energy storage management. A more comprehensive risk assessment is needed for the whole system.

At the same time, ongoing digital transformation of the energy industry offers new, smart energy solutions. Interconnected "digital" assets will make new energy ecosystems more dynamic and flexible to changes in the environment. Physical safety and cyber security of these (digital) assets are indiscernible. ■

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