End of warranty inspections in solar PV power plants

Asset management | Examining a PV power plant to ascertain its health is a key measure when warranties for components expire. Romain Elsair and Marcos Blanco of Greensolver outline some of the main steps involved in effective end of warranty inspections

The huge volumes of PV capacity deployed around the world in the past five years have necessarily shone a spotlight on how the industry manages solar power plants over their operational lifetime. A concerted effort is underway in mature markets in Europe, North America and elsewhere to standardise the approach taken to solar operations and maintenance and ensure that the most efficient, transparent and effective practices are being adopted universally by the industry.

One area that is growing in importance is the management of operational assets that come to the 'end of warranty' (EoW) period – when the warranties for individual components expire. With key power plant technologies having only a finite warranty period, each year multiple gigawatts of plants' components reach EoW, a figure that is only going to rise as the global installed base increases. When a plant's EoW period passes, new contractual arrangements may have to be renegotiated based on the current status of the main equipment, namely the solar modules, the inverters (string or central), the transformers and the mounting structure.

One source of learning for the solar industry has been onshore wind, a more mature renewable energy technology, where end-of-warranty inspections are a common practice. It is important for asset managers to have a clear understanding of the current state of the asset and overall performance linked to equipment condition. Our main role is to optimise assets under long-term contracts and therefore organising and conducting the appraisal of EoW inspections is of utmost importance.

Greensolver has been running EoW inspections on wind farms across Europe and we have been able to help and support our clients when renegotiating warranty contracts and recommend equipment improvement. As such, we believe that a similar approach can be followed when conducting EoW inspections for solar PV plants. Based on the lessons learned from its experience in managing European wind and solar assets, Greensolver wishes to share its technical views.

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End of warranty inspections of a solar plant's main componentry help with any renegotiation of contractual arrangements

Solar modules

Solar modules constitute the bulk of the BoP cost for solar projects in Europe, sometimes up to 50%. This trend is constantly decreasing due to falling prices of silicon. Therefore, it is of utter importance to understand and follow the behaviour and performance of solar modules, something that asset managers are constantly required to do.

Solar modules are typically under warranty for 25 years (that will be the peak power warranty), which is directly based on the power output of the module and a linear degradation factor applied on an annual basis (typically 80% after 25 years of operation). Filing a claim against the module manufacturer for linear degradation is a fairly complex task as the asset owner is required to use accredited laboratories which can measure module degradation with very low uncertainty. This process requires removing the modules, sending them to the lab (note: mobile labs do not currently use equipment which present measurement uncertainties low enough to provide relevant results), wait for the measurements to be performed, send the modules back and mount them back. Therefore, this is a very costly requirement, normally with a low success rate.

Solar modules also have a limited power warranty against defects for five or even 10 years. At the end of this warranty, the owner has the possibility to extend it for another five or 10 years, until the solar plant's end of life. It is worth noting that there are currently no solar plants in the UK for example (location is important as we need a benchmark, which does not exist yet) which have been operating for 20 years or more. Therefore, it can be fairly complex to forecast the future behaviour and performance of solar modules. How can the existing business model in place

take into account issues that will take place in hypothetically 10 years? There is no simple answer but experienced asset managers can help with the technical assumptions used and adjust the model taking into account module pricing, best maintenance practice, etc. and conduct EoW inspections.

These inspections will help the asset owners assess the current condition of the solar modules, focussing on cracks, thermal imaging, snail trails, yellowing/browning, potential-induced degradation (PID) issues, general state and cleanliness of the modules, MC4 connectors, back cable, maintenance history, spare parts, humidity ingress, etc.

Inverters

Inverters make up 20 to 30% of the BoP cost. Inverters are typically robust pieces of equipment and are designed to operate under changing conditions. This is especially true in the UK where cloudy skies are common features. The amount of irradiation hitting the solar plant will then vary swiftly as clouds pass away. Inverters need to respond to such conditions by having complex built-in algorithms, which attempt to maximise both voltage and current, a feature known as multi power point tracking (MPPT). Depending on the type of inverters (i.e. either central inverters, or string inverters), problems that can arise are different.

Central inverters

Solar modules are linearly connected in strings (typically a number comprised between 15 and 25) and the current and voltage of several strings are sent to the central inverters. Central inverters collect data from a large number of strings.

Central inverters can be problematic to replace or repair, especially if the issue occurs in the height of summer when production is at its peak. As a matter of fact, a large portion of the solar plant will require to be shut down for a significant amount of time to carry out the repairs, which will have consequences on the business model in place. Asset managers can anticipate when the need for such remedy happens by estimating performance of each central inverter, following the downtimes, and use internal tools for forecasting and keeping losses to a minimum.

String inverters

String inverters collect electrical data directly from module strings. For 5MWp solar plants built in the UK, it is not unusual to find about 1,000 strings and up to 250 strings inverters at one site. Therefore, chances to have issues increase as the number of individual components increases too. However, maintenance and replacement of string inverters are considerably simpler than of central inverters. String inverters are modular in nature and their repair is usually not "worth it". Each string inverter can be replaced without shutting down a significant portion of the plant as explained above.

In terms of contractual warranty, both central and string inverters are under warranty for an initial period of five years, which can then readily be extended by another five years. This process can normally be repeated until the 20th or 25th year of plant operation where the inverter manufacturer has the possibility to repair, replace or repay in case of fault/defect. However, it can become quite complicated to determine the reason for the fault/defect. Hence, asset managers can help asset owners with this task. In particular, right before the first warranty extension, it is strongly advised to run an EoW inspection and follow the current applicable standards.

EoW inspections of inverters will focus on the general state of the cabinets, check the maintenance logbook, check the SCADA system, and check and analyse the downtimes linked to inverters.

PV module warranties are among the key components that should fall under EoW inspections

Credit: Greensolver.

Transformers

Transformer units are bespoke pieces of equipment which are very robust in nature and designed for the long term, in principle they are not subject to motion, so many problems due to vibrations or mechanical adjustments normally do not affect transformers. Transformers for a 5MWp solar plant will generally have a capacity of 5MVA, but obviously other configurations do exist. In particular it is very common to find "plug and play" transformer cabinets which did not require any on-site assembly.

In terms of warranty, since fewer players are active in this side of the market, warranty can vary from 1 to 5 years. Extended warranty packages also exist to renew the terms.

At Greensolver, we have not yet met any solar PV project in the UK where transformers have suffered major incidents. However, in other jurisdictions, we can confirm that this has already happened. Therefore, a special interest should be given to the EoW inspection to analyse the state of the transformers.

Mounting structures

Mounting structures are the fundamental building blocks of a solar plant and are often neglected by technical advisors when conducting due diligence analysis. It is clear that if any serious issue arises with the mounting structures, there is no possibility to swiftly implement solutions and significant losses will occur. In particular, the galvanisation strength of the poles is of utmost importance, especially in locations where the plants can suffer from particular meteorological conditions potentially impacting its lifetime. This could be the case in places where high levels of humidity or extreme temperature ranges (for example very dry places or close to desert areas) are frequently reached, or which are subject to ice/snow during winter periods. Additionally, different metal-metal connections can often be observed (for example, steel and aluminium) and give rise to unwanted oxidation, especially in areas located close to the sea with higher levels of saline particles.

The asset manager should analyse the way the structure manufacturers have taken into account the corrosivity of the terrain leading to a defined galvanisation thickness to be coated. For example, if the lifetime of the asset is 20 years, the

warranted galvanisation thickness should be provided for 25 years. EoW inspections can help detect issues arising from galvanisation and corrosion on the mounting structures.

Emerging best practices in EoW inspections

EoW inspections driven according to the needs of the plant become very helpful for influencing the future behaviour of the plant and can help minimise costs connected to possible future failures. The possible scope of the inspection can be broad, but as best practices we recommend that the following topics are to be covered:

- **Technical design:** review of as-built documentation to ensure that the project has been constructed in accordance with the engineering design, relevant standards and regulations, EPC contract and owner's requirements; verification that the contractor has provided all documentation in accordance with the EPC contract and IEC standards.
- **Electro-mechanical installation:** inspection sampling of the plant installation, according to ISO sampling procedure standards (ISO 2859-1). This must include modules, mounting structure, DC cabling and combiner boxes, AC cabling and combiner boxes, inverters and inverter stations, security system, monitoring and SCADA systems, substation building inspection of monitoring and measurement station to be used for acquisition of on-site data and calculation of performance ratio. This can be driven by visual inspection.
- **Commissioning – functionality and safety:** review of all commissioning protocols to ensure the project has been commissioned according to the minimum requirements of IEC standards (IEC 62446) and in terms of safety for the DC and AC side, inverter functionality and grid connection.
- **System performance:** evaluation of the original yield assessment and comparison with actual as-built installation such as shading, cable laying, soiling or module handling. Completion of performance ratio tests in accordance with EPC contracts using project monitoring and measurement station.
- **O&M competency:** evaluation of O&M providers with respect to experience, references and quality assurance, as well as evaluation of corrective and scheduled maintenance programme and reports; evaluation of system availability.
- **Tests of PV plant equipment:** several tests can be driven on site or even sending some samples to accredited laboratories. In this way, the inspection reports issued can be used afterwards as a base for filing claims with product manufacturers if defects are found in the equipment. A wide range of tests can be carried out, including:
  - o Infrared tests of modules with documentation of all conspicuous or defective modules and photos of representative failures only. It must be taken into account that this test is weather dependant and a minimum solar irradiation of 500W/m^2 is required to be carried out.
  - o Electroluminescence tests on site with photo documentation of all tested modules and categorisation of potential defects. IV curve tracing on site with correction to STC conditions. Depending on the type of the mobile laboratory available on site, this test can also be weather dependant and a minimum solar irradiation of 700W/m^2 is required to be carried out.

This type of tests must establish the location of conspicuous or defective modules, marking it clearly on plant layout, joining with the identification of its serial numbers.

As a conclusion, depending on the historical overview of the plant and/or if major issues happened, it can be adapted to the needs and particularities of each plant.

Table 1. Average warranty period for key solar power plant components

Equipment	Average warranty period
Solar modules – peak power	25 years
Solar modules defects	5-10 years
Inverters	5 years
Transformers	1-5 years
Mounting structure	Should be 5+ years more than of the asset lifetime

Conclusion and recommendations

Each component in a solar plant presents its own issues. Modules bought from experienced manufacturers are less likely to present severe issues. However, it is important for the owner to understand the manufacturing practice implemented for the batch purchased. Warranties provided are very standard throughout the market but filing claims against manufacturers has proven challenging. Inverters purchased from reputable manufacturers will be proven, robust pieces of equipment. However, when failing their financial obligations, impacts will be significant and can sometimes last longer than accounted for. Transformers are also robust pieces of equipment where few instances of severe issues have been recorded in the UK. Mounting structures often appear as the "last worry" but are crucial to the correct behaviour and long-term performance of the asset.

As a recommendation, portfolio owners should be aware of each of their existing warranty contracts in place and not delay the EoW inspections of their assets, especially as their termination is on average after five years (see Table 1). EoW inspection costs are relatively low compared to the financial and production losses that could occur in the event of component failures.

Moreover, it is a common practice for large portfolio owners to have Maintenance Reserve Accounts (MRAs) in place to deal with unexpected drawbacks.

Asset managers, by conducting EoW inspections, will help asset owners take the necessary measures to mitigate risks linked to equipment warranties during the re-negotiation of each contract. ■

Authors

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