# Optimising Europe's solar plants: O&M guidelines to further solar growth

**Operations and maintenance |** Solar O&M is rapidly evolving as PV deployment gathers pace worldwide. Guillermo Oviedo Hernández, Elena Bernardi and Jörn Carstensen of SolarPower Europe's O&M Task Force look at some of the emerging trends, practices and business models in this increasingly critical arm of the solar industry

Credit: BayWa r.e.

**As O&M's importance grows, new and innovative technologies and business models are emerging**

Operations & maintenance (O&M) is key to the technical and economic performance of solar systems and plants. It is widely acknowledged by all stakeholders that high-quality O&M services mitigate potential risks, improve the levelised cost of electricity (LCOE) and power purchase agreement (PPA) prices and positively impact the return on investment (ROI) from a solar project. Today, O&M has become a standalone segment in the solar value chain with many companies specialising exclusively in solar O&M.

However, one of the main challenges facing the solar O&M industry is the discrepancies between the quality of services provided by different O&M contractors. According to a survey conducted by SolarPower Europe, two out of three solar professionals say there are "very large" or "significant" discrepancies between the quality of services provided by various O&M contractors. Reasons for this include increasing price pressure, lack of standardisation and minimum requirements, inadequate management processes, poorly qualified staff and insufficient use of digital data analytics.

Europe is the continent with the oldest fleet of solar plants, thus, proper "health care" for these plants is essential to meet performance expectations. Within this context, SolarPower Europe's O&M Task Force decided, back in 2015, to share its know-how and experience in the field, creating the first edition of the 'O&M Best Practices Guidelines'. Now, in their third edition, the guidelines have become a living document with an active community behind it, already consisting of nearly one hundred top experts from more than 50 companies. The O&M Best Practices Guidelines version 3.0 dives deeper into business models to improve O&M services with new sections on 'innovations and trends' and 'revamping and repowering'. The guidelines aim to increase awareness, consensus and encourage O&M best practice adoption by the industry, both across Europe and outside, in particular in emerging markets.

## Innovations and trends in solar O&M

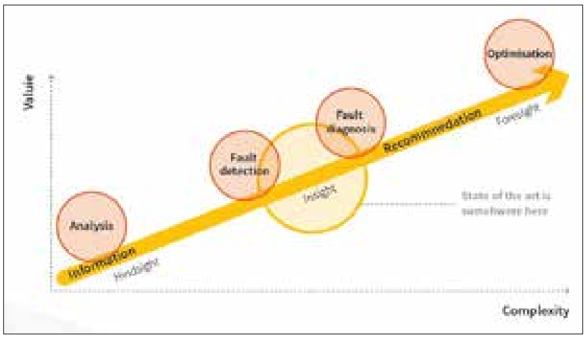
This brand-new chapter of the guidelines was motivated by the tremendous increase in solutions entering the market, which in one way or another, appealed to an innovative concept – either by doing something completely new to the industry or by doing something known, but in a smarter and more efficient manner.

According to a 2015 report from KIC InnoEnergy [1], innovations in O&M services are anticipated to reduce solar LCOE by 0.8-1.4% between 2015 and 2030. The savings are dominated by improvements in OPEX and power plant availability, and hence net annual energy production. Therefore, O&M contractors are increasingly relying on innovations to keep up with market requirements.

The O&M Task Force took on the challenge to identify and group the most important trends and innovations shaping today's O&M market. "Smart PV power plant monitoring and data-driven O&M" was identified as the most popular amongst the innovations. Let's see why.

Traditional monitoring systems generally consist of:

- On-site data loggers that collect electrical data from inverters, strings and meters;
- Meteorological stations that measure and record weather data;
- Management software then allows remote performance management, data visualisation, basic KPI calculations, reporting and alarm and ticket management.




Credit: SolarPower Europe

**Figure 1. The key aspects of data mining**

These systems, used on their own, commonly fail to detect the root causes of underperformance. The industry is therefore rapidly moving towards the adoption of 'smarter' solutions based on advanced data mining techniques. Data mining is the process of digging through data to discover hidden connections and predict trends. Sometimes referred to as "knowledge discovery in databases", the term "data mining" was not coined until the 1990s. Its foundation is comprised of three intertwined scientific disciplines, as shown in Figure 1.

Although data mining is not a new discipline, its capabilities are now being unleashed due to the potential of big data and increasingly affordable computing power and storage. Its potential to enable O&M contractors to move beyond manual, tedious and time-consuming practices to quick, easy and automated data analysis is now becoming more tangible [2].

Within this category of data-driven solutions, a number of innovations and trends were analysed, their purpose, advantages and disadvantages explained, and the state of play identified:

- Advanced aerial thermography with drones
- Automated plant performance diagnosis
- Predictive maintenance for optimised hardware replacement
- PV plant yield forecasting
- Internet of Things (IoT) and auto-configuration
- Future best practices in document management systems

Let's review here the first two as a teaser, encouraging the reader to refer to the newest version of the guidelines for further detail.

### Advanced aerial thermography with drones

In recent years unmanned aerial vehicles (UAVs), commonly known as drones, have proven to be a cost-effective tool for conducting IR thermographic inspections of large-scale PV plants. If deployed properly, they could become a cornerstone technology for effective O&M and they would not only be an activity performed just to comply with contractual obligations.

Aerial IR thermography might seem a trivial activity, and when not conducted following a set of minimum technical requirements, it is almost of no use for effective plant maintenance. However, high-quality IR images captured by a drone and their proper post-processing allow for a detailed PV module failure analysis that could trigger conclusive maintenance decisions. Furthermore, field interventions could be optimised, and PV plant underperformance could also be better understood and addressed (e.g. faulty modules that need to be replaced can be identified with precision and high-quality IR images can be used as proof in warranty claim processes).

The demand for IR inspections is growing fast, and so is the range of services offered by new players in the market, who are now pushing aerial inspections beyond basic reporting. The general services offered can be divided into two

**Drones are become an integral aspect of cutting-edge O&M practices.**

Credit: BayWa r.e.

main activities: data acquisition and post-processing.

In data acquisition, a flyover is performed in which raw IR images and visual photos or videos are recorded. Depending on the provider, additional geolocation services and 3D modelling of the entire plant may be offered. Some other solutions provide additional sensors to record weather variables (usually irradiance and ambient temperature) during the flyover.

The post-processing activities consist of all the data processing and analysis techniques to be carried out to produce the final report and all the related deliverables. These activities can be done manually or automatically by means of specialised software.

The data acquisition stage is now well understood as drone technology ripens and becomes a trend. There are already many companies that offer high-quality industrial drone flights. Usually companies using drones as a daily work tool do not only conduct IR inspections of PV plants, but also industrial aerial inspections of oil ducts, off-shore oil extraction platforms, roads, bridges and wind turbines, just to name a few. Therefore, the data acquisition stage is an activity that could be easily outsourced by O&M contractors, mitigating the risks related to technology obsolescence and avoiding the costs of regular drone maintenance.

Most companies today still rely on manual data processing, which represents a big drawback for large portfolios as human error drives down the accuracy of thermal imaging assessment. This means that companies with automated solutions have a huge advantage in this regard.

Aerial inspections and their associated post-processing activities are evolving very rapidly, and the quick adoption of new technologies is of high strategic importance in today's highly competitive O&M market.

## Automated plant performance diagnosis

As described in SolarPower Europe's 'Global Market Outlook', the PV industry showed in 2017 the highest growth in the energy market, with a total capacity of nearly 100GW installed worldwide. In such a context, PV plant reliability is subject to higher reliability requirements. With special consideration for ageing plants in Europe where the secondary market is growing, automating diagnostics of PV assets is crucial.

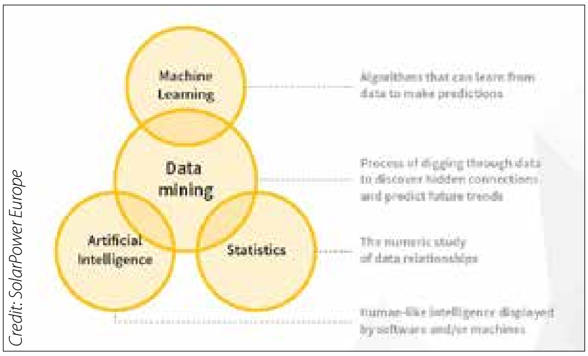



**Figure 2. Automated plant performance diagnosis**

Until now, plant performance assessment has typically been executed in a top-down approach, analysing low performing objects by drilling down from substations and inverters to junction boxes and strings. This process is time consuming and expert-dependent. Furthermore, the process does not guarantee revealing all underperformance issues.

Automated bottom-up diagnosis using advanced big data mining techniques can overcome the disadvantages of classic plant performance assessment by experts: time saving of expert data handling, less error prone and better diagnosis performance.

Big data mining algorithms have been successfully applied to solar plant data and have proven to reveal performance issues beyond top-down expert analysis in a semi-automated way. Further R&D into this subject area serves to make the algorithms more robust for automated application on large portfolios and capable of root-cause failure identification.

## O&M for power plants equipped with battery storage systems

In recent decades, to reduce the pollution and the consequent effects on the environment, society realised that it is necessary to rethink the way in which energy is generated and used. The renewable energy resources penetration and uncontrollability has motivated the development of technical challenges to efficiently deliver sustainable, economic, and secure electricity supplies. In this context energy storage is playing an important role to assure the stability of a system creating value on the market to balance the intermittency of renewable generation.

Energy storage systems (EES) are a set of technologies whose aim is to decouple energy generation from demand. The system is planned to store the excess energy produced and release it during periods of high electricity demand or scarce production, ensuring a steady electricity supply, especially in remote areas where the national grid is unstable.

Battery technologies can be classified according to their energy density, their charge and discharge characteristics, system integration and the costs. Despite there being many forms of EES (flywheels, compressed air, thermal etc), the most mature and commonly used systems for solar plants are solid state batteries (e.g. lithium-ion) lately being improved in terms of characteristics, thanks to the automotive industry's research into electric vehicles.

Nowadays, there is a growing interest in flow batteries, in particular the vanadium redox, due to its great degree of flexibility and scalability. Their most fundamental characteristic, differing from the lithium-ion technology, is that power and energy are completely independent, which may represent a considerable advantage in specific applications.

According to producers' indications, if maintained correctly, flow batteries typically last 25 years against the 15 years of the solid state. Due to their peculiar characteristics, each technology is preferably applicable in specific scenarios where a short-term response is needed. To give an example, solid state batteries, which contain a higher C-rate, can discharge quicker and more effectively in "blackout" situations, where a large amount of energy over a short period of time is required. For their part, flow batteries are very efficient for meeting a steady, long-term energy demand such as night-time application.

The above-mentioned ESS are subject to significant health and safety risks. In order to prevent hazards or an uncontrolled release of energy, an appropriate risk assessment must be performed during the design, planning and maintenance phases. Different players in the market are developing solutions to mitigate health and safety risks, offering alternative products which are non-toxic, non-flammable and safe to transport and store. Amongst the others, salt water batteries can be mentioned for their "environmentally friendly" way of storing electricity power, despite their disadvantage of being very heavy and space intensive.

To increase the reliability of an ESS, an efficient energy management system (EMS) to track the state of components is essential. The EMS should also gather data coming from energy meters and operating parameters, such as temperature, voltage, current, power level, state of charge, state of energy and warning messages.

Despite this, energy storage is considered a technology that has the potential to disrupt the energy market, but an additional effort is required in order to support its diffusion. The reduction of their high capital costs and a regulatory framework definition is necessary to accelerate the removal of barriers to the deployment of storage.

## Major opportunities with revamping and repowering

The solar industry has seen several spiking phases of new installations as the international market has grown and regional regulatory frameworks have changed. By the end of 2018 we reached more than 500GWp of PV capacity installed worldwide. Whilst the industry is picking up speed, we see that ageing PV sites naturally develop an increasing demand for corrective maintenance with a parallel potential for repowering measures.

On the one hand, degraded or defective modules as well as inverters lead to increasing failure rates and yield losses, which makes repair or exchange works necessary. This demand is often accompanied by the fact that several manufacturers and service providers of these components have meanwhile left the market, which results in a significant unavailability of spare parts and support for plant owners.

On the other hand, technological improvements in efficiency and falling prices for these components often create feasible economic scenarios for an exchange of old modules or inverters with new and more powerful models. Furthermore, repowering projects usually include additional benefits, such as new warranty terms and compliance with the latest regulatory adaptations. This development is the reason why revamping and repowering of PV plants is getting more and more popular. That said, the increasing significance of repowering and revamping in the solar industry also gives added reason to create standardised ways to address the challenges in this field – the O&M Best Practices Guidelines offer a great opportunity to discuss and build these standards.

## Defining repowering and revamping

Revamping and repowering are defined as the replacement of old power production-related components of a power plant with new components to enhance its overall performance. Revamping involves component replacement, but without substantially changing the plant's nominal power, whereas repowering involves increasing it. The difference to ordinary replacement lies in the aim of increasing the performance by exchanging all components within a functional area or a significant ratio of them. The aspects and consideration in the following sections focus on repowering but apply in most cases also for revamping and even repair and extraordinary maintenance. There are numerous ways of repowering a PV plant. In the following paragraphs we will concentrate on the two most important opportunities of module and inverter repowering.

*Credit: greentech*

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## Module repowering

Degradation, underperformance or simple defects in modules which are not repairable or available for direct replacement on the market may force the investor to consider module repowering. This can be carried out for the entire PV plant or for specific parts. When the repowering is focused on a partial module replacement, it is recommended to exchange some more modules than technically required, to keep some intact old modules as spare parts for the future. Due to the fast development of PV technology, it is not very likely that the same components are still available on the market in the required quantity or at a competitive price. Certainly, exchanging the identical modules would make a repowering very simple, but this would also reduce the utilisation of the repowering opportunities in lower price and higher efficiency. In case different modules are to be used for the repowering project, the following aspects need to be considered during planning and executing:

### Mechanical installation

- If the modules have different dimensions or weight, the compatibility with the mounting system needs to be considered. In extreme cases a new mounting structure is required.
- Adequate integration of the new modules into the grounding system.

### Electrical installation

- Depending on the electrical characteristics of the new module type a new string design can be inevitable.
- A mix of different electrical characteristics at one inverter or at least one Maximum Power Point (MPP) tracker

should be avoided.

- Most likely the new module type will have different connectors. Accordingly, the string cable connector needs to be replaced.
- The dimensioning of existing cables and fuses needs to be checked and verified to be suitable for the new DC-layout.

Further considerations with regard to regulatory aspects or additional synergies are reflected in the O&M Best Practices Guidelines in more detail.

## Inverter repowering

As with all electronic devices, inverters have a limited lifetime. With increasing age and wear, the likelihood of failures and breakdowns increases. If the warranty of the device has expired, a technically and economically suitable solution needs to be identified. If an identical replacement inverter, repair services or spare parts are not available, the exchange through a new component is inevitable. There are different strategies for inverter repowering which should be evaluated on a case by case basis:

**Partial or complete exchange:** If not all inverters are affected, a partial exchange of the inverter fleet can be an option. This potentially reduces the overall costs, but it can also increase the complexity of the repowering project.

**Exchange of same or different power class:** Exchanging inverters with the same power class is easier for the DC and AC integration. However, replacing multiple devices through one with a larger power class can increase the system efficiency and reduce the component costs as well as future maintenance costs.

When an inverter repowering is planned, several factors need to be considered:

**Mechanical installation:** If the new inverters have different dimensions or weight, a suitable solution for the installation or mounting of the inverter needs to be prepared. The same accounts for a proper cabling if DC or AC connections are changed. The manufacturer of the new device might have different requirements for the mounting with regards to fixings, distance to other components or to the roof, ventilation, etc. All requirements need to be checked and implemented. The new inverters need to be integrated into the grounding system according to the standards and the manufacturer's specifications.

**Electrical installation:** The integration of the DC side to the new inverters needs to follow the DC input requirements of the new inverter. Eventually, the string length and the number of connected strings need to be adjusted to suit the technical parameters of maximum current and voltage as well as ideal operational conditions. If different inverter sizes are installed, the integration to the AC side needs to be re-engineered. This includes the cable diameters, protection devices (fuses) and connectors. In any case the applicable electrotechnical rules and regulations need to be followed.

**Communication system:** Before choosing an adequate inverter, the compatibility with the physical communication cables should be checked. The installed data logger needs to support the new inverter's data protocol. Otherwise, an update or the exchange of the data logger will be required.

## General repowering considerations

Although a repowering project is mainly technically driven, for the owner of the PV system it is a commercial re-investment case. Therefore, it is of great importance to calculate a detailed and solid business case before the project and review it during the project stages. All technical and commercial data, such as historical performance, future performance, revenues, costs, extended life span and changed maintenance requirements need to be considered to come up with a prognosis of the future income streams. With this, a classical return on investment or break-even calculation can be performed and presented to the investor as a decision basis.

As an additional analysis, it is recommended to calculate the sensitivities of the most important factors. This will provide a better understanding of the influence of changing conditions, e.g. if the costs for the project will change or the projected performance will be different to the assumptions.

Each repowering activity should be approached as an individual project with clearly defined project phases, responsibilities and budgets. A sample project structure can be found in the O&M Best Practices Guidelines.

## Conclusion

Responding to the discrepancies that exist in today's solar O&M market, the SolarPower Europe O&M Best Practices Guidelines make it possible for all to benefit from the experience of leading experts in the sector and increase the level of quality and consistency in O&M. These guidelines are meant for O&M contractors as well as investors, financiers, asset owners, asset managers, monitoring tool providers, technical consultants and all interested stakeholders in Europe and beyond. SolarPower Europe is committed to supporting the industry to improve best practices to deliver the most efficient, innovative and cost-effective solar healthcare services. ■

***SolarPower Europe's O&M Best Practices Guidelines can be downloaded at www.solarpowereurope.org***

## References


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## Authors


The authors of this article are members of SolarPower Europe's O&M Task Force and co-authors of the O&M Best Practices Guideline Version 3.0.

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