Return on Experience
on the post-construction performance assessment of **77 operating PV plants**

Stéphane Vidal - Head of Engineering – December 2015

Introduction

KiloWattsol is an independent technical advisor and a specialist in the analysis of performance of photovoltaic power plants. Matching the maturity level of the PV market, over the past three years, kiloWattsol has been commissioned to assess the performance of 395 operating plants. Generally these analyses are performed when there is a transaction, either for the buyer or seller. Out of all of these plants, 77 have been subject of a comprehensive analysis. This document presents the feedback gained from these detailed studies.

The aim of these post-construction yield studies is to assess the future generation capacity of the power plants primarily by using the production data recorded during the operation period. They also include an evaluation of the downtime rate and the degradation factor for the considered period. In some cases, a site visit was also performed which allowed to identify the cause of the downtime or degradation for that specific site.

Most of the reviewed power plants are ground-mounted solar parks but the study also includes some industrial PV-roofs. The 77 plants are primarily located in Europe and have a nominal power of several megawatts peak with a cumulative capacity of 392 MWp. The analysed periods vary widely from 6 to 58 months with a mean of 24 months.

This document synthesizes the feedback obtained, specifically the observed values of downtime and degradation, by applying kiloWattsol's analysis methodology.

Methodology

KiloWattsol's post-construction yield assessment methodology consists on adjusting the metered production data taking into account the particularities of the period with reference to the average long-term.

When choosing the reference material, kiloWattsol favours factual production documents such as the grid-operator monthly statements. The temperature and irradiation climate particularities (referred to as anomalies) are determined in order to neutralize their influence. All downtime for the period is quantified through a detailed analysis of the monitoring data. Their causes and potential corrective actions are considered in order to establish a long-term production estimate.

Representativeness of the results

All studies were carried out at the request of kiloWattsol's clients for a specific purpose. Most as part of a loan refinancing exercise, or a transaction, hence requested by the buyer or the seller. This is likely to introduce a bias in the sample and thus on results' representativeness.

Some of the reasons behind the client's requests are:

- A power plant had downtime issues from the beginning, they have now been solved and the client would like to quantify the production capacity to capitalize on this potential (when a plant is being sold).
- A power plant is outperforming the initial yield study estimate and the client needs

an independent evaluation to attest of its true capacity (for example, as part of a refinancing).

- A client suspects there is an abnormal decline in performance and wants an independent study to attest his theory and size the potential loss (for example, as part of a warranty claim).

Given that the selection of power parks analysed by kiloWattsol are not statistically representative of all installed PV plants, the results of this document do not become typical for industry as a whole.

Downtime

When the quality and granularity of the available data allow it, kiloWattsol determines the downtime of each month of the studied period by conducting thorough analysis of production profiles. A power quantification is performed taking into account the electrical grid failures, maintenance and equipment breakdowns.

It should be noted that most service contracts specify a way to calculate the downtime and they are different from the method used by kiloWattsol. In some instances, the contractual method may exclude specific issues like the grid outages, therefore, displaying lower downtime rates.

KiloWattsol also notes that maintenance providers sometime miss issues when calculating the downtime because they are below their detection capability. This is caused by an inadequate supervision system and/or a lack of surveillance.

KiloWattsol has found that it is possible for a PV plant to operate with a very low downtime (<0.5%) provided certain conditions are met: the use of reliable equipment, an effective monitoring system and a reactive maintenance. A dedicated staff committed to the optimum operation, located nearby and with access to an appropriate stock of spare parts is necessary.

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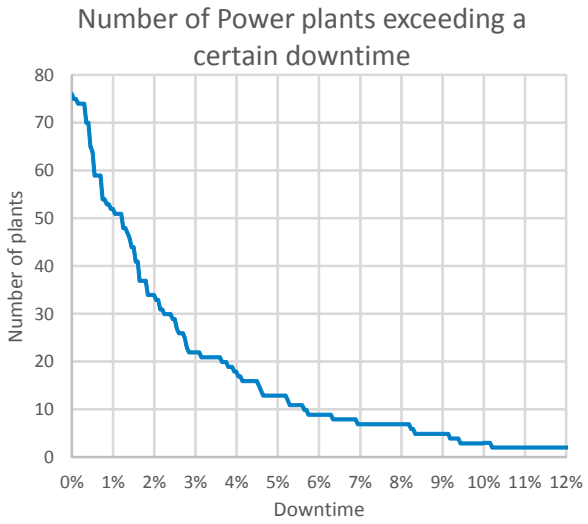
Overall, the observed downtime is often high with a sample mean of 2.9%, half of the studied power plants exceeding 1.6% and 13 exceeding 5%.

Nevertheless, these figures must be put into perspective. The time frames analysed often correspond to the first years of operation where failure rate is generally higher. In addition, post construction studies are often requested precisely because major outages are occurring.

The following graph represents the downtime found on the 77 detailed studies performed by kiloWattsol.



The main sources for downtime that kiloWattsol found are:

- Inverter issues
- Transformers issues (some of which have burnt)
- Electrical grid instability issues
- Junction boxes or strings being disconnected for long periods of time
- Stolen cables
- Tracking system Issues

It should be noted that the most significant downtime incidents are driven by slow response time from service team or lack of spare parts. KiloWattsol identified instances where inverters were down for several months in a row.

Similarly, grid-related losses are due, for the most part, to the time it takes for the inverters to reconnect after a grid fault. It is likely that the fault itself was very short.

Aside from the cases where a guaranty claim can be made, either directly to the manufacturer or to the insurance company, the production losses due to the downtime represent a significant loss of revenue for the owners. Even though, in many cases, they are not aware of these issues.

Performance drop

The performance drop of a photovoltaic plant or "the degradation of the system" is quite difficult to assess, especially because of climate variability. The module degradation is not the only factor causing loss of performance. This is the reason why kiloWattsol prefers to use the term "performance drop". KiloWattsol has developed a methodology that allows to quantify the performance drop. In order for the results to be relevant the analysis period must be long enough, ideally more than 24 months.

It was only possible to find a performance drop value for 37 out of the 77 studied plants. The annual performance drop varies from 0% to 4%, with an average value of 1.3% and a median of 1.1%.

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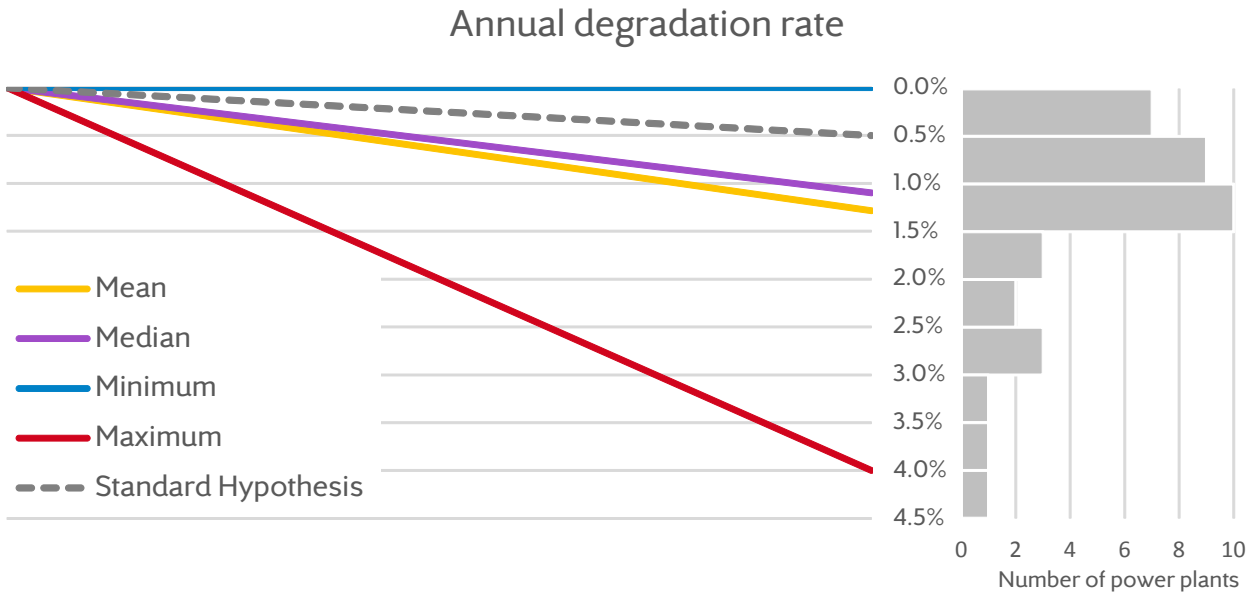
These results come from a sample of plants with known degradation problems, explaining the relatively high rate. Moreover, the studied time period corresponds to the first years of operation of the power plants. The loss due to certain phenomena will not necessarily continue to affect the performance at the same rate in the future, it could slow down or plateau.

Nevertheless, performance degradation is significant, and often, has gone unnoticed by both the maintenance providers and owners. Most supervision and monitoring systems do not allow the detection of these performance drops before 3 or 4 years of production have passed.

The graph bellow shows the performance drop that was found on the 37 studied power plants.



The main causes for the performance drop are:

- A progressive degradation of all of the modules
- A high degradation of part of the modules due to delamination, broken glass or micro-cracks
- A build-up of soiling
- Vegetation growth creating shadow
- Strings being disconnected and gone unnoticed

Specific corrective actions can be triggered by identifying and quantifying the performance drop. For instance, warranty can be claimed on the modules, cleaning can be scheduled or the vegetation could be cleared. The earlier the issues and their cause are identified, the greater the potential financial gain is.

Production vs. preconstruction study

When kiloWattsol is commissioned to perform a post-construction yield assessment, the initial yield report is not necessarily available. Additionally, in some instances, the initial design of the plant has changed after the yield study was performed (for instance changing the module model, inverter, table tilt or nominal power) making a direct comparison between the performance analysis and the initial yield study irrelevant. Therefore, kiloWattsol cannot produce a comparative analysis of the result for the 77 studied plants. However, the actual recorded performance, adjusted for peculiarities of the period, rarely deviates from the expected performance.

KiloWattsol has found that usually more attention is given to the plants that seem to be underperforming due to an optimistic initial yield study. Conversely, plants that seem to work well based on a conservative initial yield study are subject to less attention while the potential gain is often greater and very likely going unnoticed.

The potential financial gain is significant especially in older plants for two reasons. In the past yield studies were usually conservative and thus it is likely for a plant to be performing below optimum without anybody knowing. And because older plants were granted high feed-in tariffs.

KiloWattsol considers that it is important determine the true capacity of a power plant after the first or the second year of operation, and no longer refer to the original yield study. This gives a more precise reference that can help to detect problems faster in the future.

In general, downtime and degradations found on the early years of operation of the 77 studied power plants are rather high. These rates will not necessarily be at the same level in the future.

Large disparities were found in the way that different plants are being monitored. Many of the downtime events and performance drops had gone unnoticed. KiloWattsol has studied PV plants that run almost perfectly, but to achieve this, they require rigorous supervision.

About kiloWattsol

KiloWattsol is a spin-off of the Building Science Laboratory (LASH, an associated Research Unit with the CNRS) of the French national school of civil engineering (ENTPE). The company was created in 2007, after 10 years of research on the characterization of the daylight illuminance.

The team is formed by specialist engineers in the fields of climate analysis, electricity, IT and statistics. They developed a unique know-how and a state of the art methodology for the evaluation of a solar power-plant's potential and the quantification of associated risks.

Since its creation, the company has been involved in over 1,400 photovoltaic projects on four continents.

If you have questions about the company, its references or elements of this document, please do not hesitate to contact kiloWattsol at +33 (0)4 27 86 82 47 or visit www.kilowattsol.com

kiloWattsol
solar resource expert