Revolutionizing Solar Performance: Unlocking Solutions for Underperforming Assets

Solarlytics

Solar power has emerged as a dominant force in the United States, promising exponential growth in the coming decade. Projections indicate a remarkable 350% percent growth in installed PV capacity in the US in the next ten years, catapulting solar energy to contribute nearly 30% of the nation's electricity. However, this excitement sometimes is tempered by the growing dissatisfaction among investors grappling with lackluster returns. At the heart of the issue is system underperformance.

Performance Challenges

The 2023 Solar Risk Assessment by kWh Analytics reveals a disconcerting reality – solar assets in the US are trailing their P-50 levels by an average of 8%. In any energy sector, an 8% underperformance is unacceptable, yet, regrettably, it has become the status quo in the solar industry. What's even more troubling is that 50% of the assets in the study perform even worse than this benchmark. As the industry continues its massive expansion, it is imperative to analyze performance dynamics, identify design and equipment pitfalls, and find cost-effective solutions to ensure solar assets meet and exceed investor and off-taker expectations.

Solarlytics' BOOST Platform is a fully integrated IoT hardware and cloud solution that provides immediate performance improvement, voltage control, data collection and analysis, and cost-effective aging equipment replacement. The system also enables parallel "mixed field operation" of new and old modules on the same inverter.

Solarlytics, a California-based tech firm, specializes in addressing these challenges. We aim to optimize solar field performance, maximize energy production, and ensure better returns for asset owners and investors. Over the last 4 years, Solarlytics has collaborated with large-scale solar asset owners throughout the country to analyze underperformance issues and develop machine-learning based solutions, including the BOOST Platform. While myriad factors contribute to underperformance, 5 primary categories stand out: voltage collapse, string imbalance, failing inverters, lack of data driven operations and maintenance, and equipment in need of repowering. These issues substantially threaten energy production, often manifesting from the initial commissioning phase.

Voltage Collapse

- Voltage collapse occurs when the solar array's peak power voltage misaligns with the inverter's operating range. Misaligned power voltage is typically due to wide temperature fluctuations, particularly during warm weather periods.
- Solarlytics' BOOST Platform addresses this issue by increasing and maintaining the array's voltage within the inverter's range, mitigating energy loss during warm weather months.

String Imbalance

- String imbalance disrupts overall solar field performance due to uneven energy distribution. This is typically caused by equipment failure, topography, shading, mismatched modules or strings, and other issues that create misalignment of strings.
- The BOOST Platform employs a dedicated maximum power point tracker "MPPT" for each string, maximizing power output and adjusting string voltage to ensure efficiency and recover lost energy.

Failing 600V Inverters

- Industry-standard 600V inverters from a decade ago are now underproducing or failing, and no manufacturer is producing 600V replacement inverters. Solarlytics' BOOST Platform acts as an intelligent adapter, seamlessly integrating higher voltage, higher-performing inverters without the need for costly restringing.

Maintenance Challenges

- Non-data driven maintenance practices, including missed maintenance, and undetected/undiagnosed issues, lead to significant reduction in energy output. The impact of unperformed maintenance, unplanned downtime during maintenance, and problem source identification reduce energy production and decrease maintenance efficiency.
- The BOOST Platform collects high-resolution data, enabling precise problem identification and machine learning diagnostics for proactive issue resolution, significantly improving maintenance efficiency.

Repowering - Mix and Match

Replacing or upgrading modules in aging solar arrays presents logistical challenges. Newer modules have higher efficiencies, different form factors and electrical values. The BOOST Platform enables mixed-field operations by decoupling old and new modules electrically, maximizing production and minimizing downtime. This is realized as each string or pair of strings is run on its own maximum power point tracker. The DC output is then combined at a defined voltage at the inverter which can still manage its operation in either fixed voltage mode or MPPT tracking thus maintaining the inverter grid functions for phase shifting or curtailment as the case may be.

What can you do to improve PV energy production?

Knowing the problem in the field is challenging enough but finding a solution can be even more difficult. That is why we created the Solarlytics BOOST Platform as a singular solution to address all of these issues. The Solarlytics BOOST uses IoT hardware, detailed data collection and machine learning analytics to provide solutions to some of the industry's most pressing issues, including:

- Correcting voltage collapse issues without replacing the PV modules or inverter
- Normalize string imbalance created by mixing new and legacy PV modules on the same central inverter
- Increase DC loading without overloading the existing inverter or electrical BOS
- Recover energy lost from variable degradation and other sources of mismatch
- Replace legacy inverters with modern inverters without costly and time consuming rewiring
- Pinpoint necessary maintenance with precise solutions with real-time knowledge monitoring and analytics

The Solarlytics Boost Platform improves the performance of existing large-scale PV systems. Due to its unique approach, expenses typically associated with equipment replacements and upgrades are mitigated, resulting in lower costs, faster remediation time, and stronger financial returns.

Addressing Voltage Collapse

Voltage collapse emerges as a critical issue affecting energy production when the solar array's peak power voltage misaligns with the inverter's operating range - the DC bus voltage falls below the inverter's required level to produce its AC output voltage at full available power.

When the plant is new, the solar array and inverter are aligned, as shown in Figure 1, and the maximum energy is transferred from the solar array to the inverter.

Figure 1 illustrates the alignment:

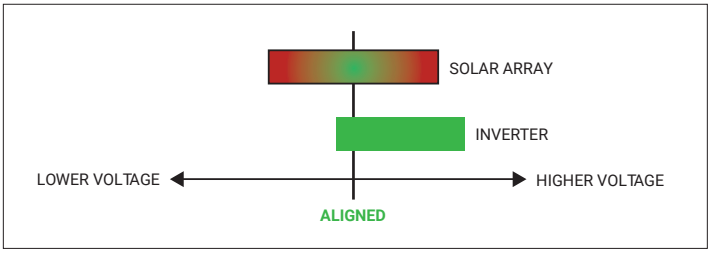

Figure 1. The Solar Array and Inverter Operating Range are Aligned. The center portion of the solar array's operating range, corresponding to peak power voltage, is within the inverter's MPPT (maximum peak power tracking) range of the inverter.

In contrast, alignment becomes a problem as the solar array ages and modules degrade, especially when warm weather reduces the module voltage. As shown in Figure 2, the solar array voltage collapses and shifts to the left.

Figure 2 illustrates the misalignment:

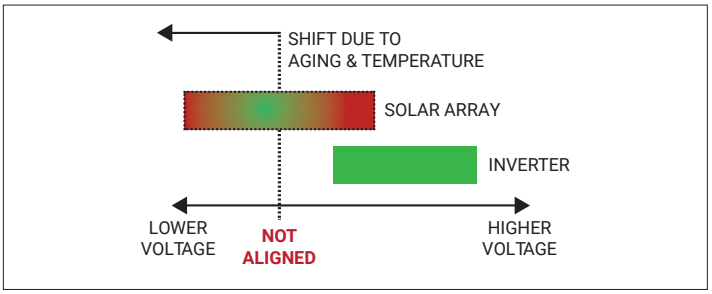

Figure 2 . Misaligned Solar Array and Inverter Operating Range. Aging and warm weather create a voltage misalignment resulting in a loss of energy production.

The solar array's peak power voltage and the inverter's MPPT range are no longer aligned, resulting in a loss of energy production. The problem is further exacerbated if the grid operator requires the site to produce higher voltages. A required AC voltage increase shifts the inverter's operating range to the right, creating even greater misalignment.

Voltage collapse problems can be difficult to address because they are expensive to both ignore and fix. Ignoring the problem results in lost revenue from low energy production. To address this issue, correct alignment must be created between the solar array and the inverter - the PV field and the inverter need to work together. The optimal cooperation must be engineered for the local temperature profile and grid voltage, so the string voltage fits nicely in the inverter operating window. This can be achieved through the expensive effort of replacing large numbers of modules or swapping inverters. Or the asset owner can utilize a much more cost-effective solution by installing the Solarlytics BOOST Platform, which solves voltage collapse and increases energy production by aligning the solar arrays' voltage with the inverter's operating range. See Figure 3.

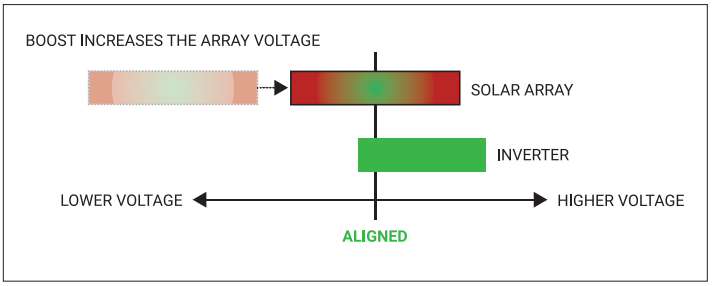

Figure 3. BOOST Realigns the Solar Array Voltage with the Inverter Operating Range.

By maintaining the correct voltage range, asset owners can maximize energy transfer from the solar array to the inverter.

Addressing String Imbalance

String imbalance leads to uneven energy distribution across the solar field and affects energy production. Central inverters maximize energy production when all the connected strings perform equally. String imbalance occurs when the performance of one or more strings differs from the other strings feeding into an inverter, resulting in a loss of energy production. There are many sources of string imbalance, including:

- **Terrain:** Arrays not mounted in a co-planar fashion will be imbalanced, resulting in energy loss. This is common when sites are implemented on uneven terrain, such as a rolling hillside.
- **Uneven Aging:** Solar modules degrade in power at a rate of 0.5 to 1.2% per year. Unfortunately, the degradation is not necessarily uniform amongst modules. The difference in degradation over a period will create a string imbalance.
- **Temperature Gradient:** Uneven temperatures across a solar field will result in string imbalance. Due to airflow, the temperatures of modules on the edges of a solar site are considerably lower than in the center of the site. Since older p-type mono- and poly silicon modules degrade at a rate of @0.4% per degree C° difference from 25 C°, a 10° difference equates to a 4% string imbalance, resulting in a loss of energy production.
- **Mixed PV Modules:** When new PV modules replace a legacy PV module due to module failure or damage, string mismatching can occur, creating a string imbalance.
- **Shading and Soiling:** Solar arrays are susceptible to shading from vegetative growth, soiling and other factors. If plants grow faster than the contracted vegetation management can control them, different strings will have different performance levels.

- The BOOST Platform is specially designed to overcome the impact of string imbalance in two ways:
  - The Boost Platform maximizes the string's peak power through maximum power point tracking (MPPT) dedicated to each string instead of a single MPPT in the central inverter used for all 50-200 strings. As a result, each string operates at maximum power, increasing energy production.
  - The string's output voltage is increased to a range compatible with the inverter. This allows the inverter to operate with a high, fixed voltage bus while each string delivers full power. As a result, the system captures energy production that would otherwise be lost.

By maximizing the string peak power, asset owners can maximize energy transfer from the solar array to the inverter.

Addressing End-Of-Life 600V Inverters

600V inverters were the industry standard in PV installation 10 years ago. These 600V inverters are at end-of-life; most are underproducing and many have failed. They need to be replaced, but replacement 600 V inverters are no longer available; 1000V and even 1500V have become the industry standard.

Since the replacements are incompatible, restringing the modules on the tables/trackers is necessary. This is costly and time-consuming, particularly if row-to-row underground

cabling or completely new homeruns to the recombiners or central inverters are required. Installation labor and prolonged plant downtime make this an expensive and time-consuming solution.

The BOOST Platform performs as an intelligent adapter that allows legacy inverters to be replaced by higher-performing commercial inverters. The BOOST Platform can be set to increase the voltage from the PV array to a fixed level within the new inverter's operating range, allowing new higher-capacity inverters (1000V or 1500V) to be used in place of the existing inverter and deliver full available power from the PV array. By mitigating the need to replace the strings, inverter replacement becomes considerably less expensive, awarding the asset owner a stronger ROI.

Addressing Effective Maintenance Practices

Missed maintenance and undetected/undiagnosed issues can significantly reduce energy output. The impact of unperformed maintenance, unplanned downtime during maintenance, and problem source identification reduce energy production and decrease maintenance efficiency. The asset owner often has limited visibility into the underlying causes of underperformance.

The BOOST Platform improves maintenance by providing high resolution data. Current, voltage, power, energy, and module temperature are collected at the string level and recorded in the Solarlytics' Cloud every 30 seconds. The data is aggregated and made available to the plant SCADA system for the customer and the operations and maintenance provider. It becomes a useful tool for the O&M (operation & maintenance) to spot problems in addition to visual inspections, drone snapshots or other means. In addition, the BOOST Platform utilizes machine learning based diagnostics to automatically identify potential issues in the array without the need for human manual analysis, and provides the asset owner with specific recommendations for improved O&M. This information allows the O&M team to make an informed decision whether the identified issue warrants an immediate field trip or not. The BOOST Platform significantly improves energy production due to enhanced maintenance.

Addressing Repowering with mixed fields of old and new modules

If the existing modules have defects of mechanical or electrical nature, they must be retired. Filling the gaps with new modules is not an option. Therefore, the broken modules are removed and replaced with salvaged modules from other portions of the site. This creates multiple empty strings that can be filled with new modules on the old racking. This "soft repowering" creates string imbalances, which will limit the production of the new modules.

With BOOST the old and new strings are electrically decoupled. Each string is operated at its maximum power point and the BOOST outputs are then combined through the existing combiner and DC cabling into the central inverter. With BOOST, a site can have a combination of new and old modules and maximize production.

Software is at the Heart of the BOOST Platform

Solarlytics' BOOST Platform uses SolCloud™ monitoring and machine learning to maximize energy production. String performance data measured by the BOOST unit is passed to the Cloud every 30 seconds. This high-fidelity temporal data enables insights into string performance not possible with traditional inverter level or other monitoring system sample rates of 15 minutes. These insights include failing by-pass diodes, panel shorts, shadowing, and more. With high resolution data, operations and maintenance are enhanced thereby improving energy production. The SolCloud data can be made available to existing monitoring or asset management platforms through an application program interface API.

Machine learning is employed on the BOOST Platform to enhance energy production in two ways.

- First, Solarlytics has developed and patented an enhanced MPPT algorithm called BOOST Plus that responds substantially faster to irradiance changes common in Eastern North America, Hawaii, or Northern Europe. Under such conditions conventional MPPTs lose energy due to the time required to locate peak power during changing irradiance. In contrast, BOOST Plus harvests more energy as it sets peak power in milli-seconds.
- Second, Solarlytics Machine Learning pattern recognition algorithms can automatically identify potential solar field problems such as short circuits due to moisture, shortfalls in predicted energy production compared with the original yield prediction out of the bankability study, and more.

Machine Learning based pattern recognition algorithms are powerful tools which will take Operations and Maintenance as well as Asset management to the next level while improving energy production.

Conclusion

The solar industry is slowly realizing that utility and C&I assets are underperforming and, in many cases, underperforming significantly. Solarlytics is committed to solving these problems and maximizing energy production at solar plants. Our fully integrated IoT hardware and machine learning software solution provides immediate performance improvement, data collection and analysis, voltage control, easier repowering and aging equipment replacement all in one package. Our solution enhances any installation regardless of equipment, technology, age, location, or changing light conditions. By addressing voltage collapse, string imbalance, end-of-life equipment and implementing effective repowering and maintenance practices, the BOOST Platform empowers asset owners and investors to achieve optimal returns.

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