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Data-driven Approaches to Improve Solar Photovoltaic Operations and Maintenance

Introduction

Ninety percent of PV plants operating globally have been built in the past seven years, yet these plants are anticipated to last for at least twenty years. EPRI is applying various data analytics and machine learning methods to operations and maintenance (O&M) data collected from operational large-scale, ground-mounted solar photovoltaic (PV) plants with the goal of hastening the creation of O&M best practices. Operational expenses comprise approximately one-quarter of the total lifetime costs of a PV plant and are critical for producing the expected energy and, by extension, generating reliable and affordable solar electricity.

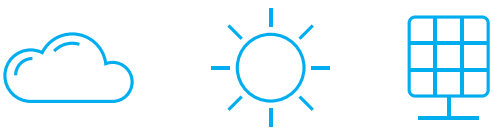
The disparate geographic locations, remoteness, relatively small nameplate capacity, and highly digitalized hardware of most PV plants is well-suited for remote operations. Research is actively underway to determine how to best collect, analyze, and derive knowledge from PV plants for such purposes as:

- Increasing energy output and reducing costs by optimizing the quantity and quality of sensors versus the faults and failures that can be detected,
- Automatically detecting and diagnosing underperformance and minimizing false alarms through the development and application of machine learning algorithms,
- Optimizing preventative maintenance activities and frequency by applying machine learning algorithms to derive information from historical maintenance logs,
- Developing better bases for budgeting maintenance through statistical analysis of past equipment faults and failures, and
- Informing decisions around balance of data quantity, quality, and type against knowledge that can be derived.

Improving PV Operations

PV plants are highly digitalized, often comprised of modular power blocks, and intrinsically able to self-report some health information and collect a large number of performance-related data channels. It is incumbent upon the plant owner / operator to decide what data to collect, in what time intervals, and how to turn it into actionable knowledge. ***EPRI is currently applying the most promising machine learning techniques[1] to improve the efficiency, efficacy, and productivity of PV operations.***

Partly cloudy days can cause multiple underperformance false alarms in operations centers.



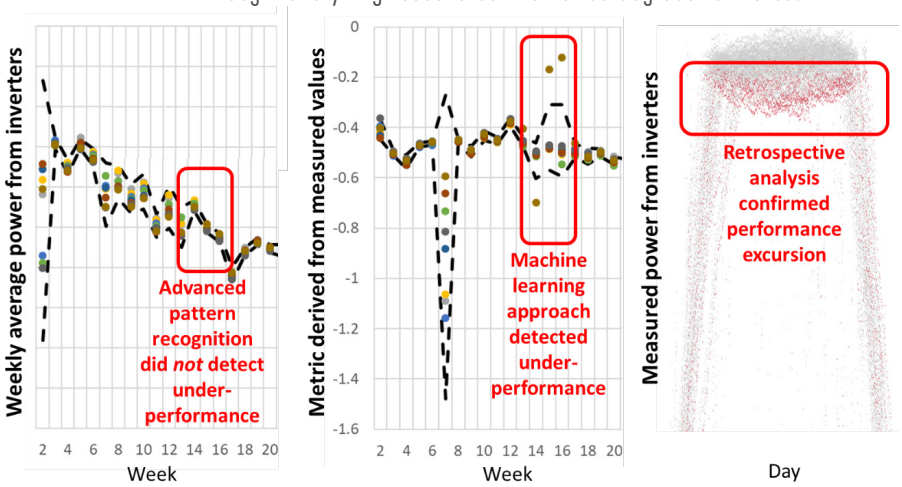
1. *Data Analytics for PV Systems: Fault Detection and Diagnostics*. EPRI, Palo Alto, CA: 2019. 3002015051.

A variety of on-going projects are yielding new insights about how PV plants perform in real-time and over their lifetime:

- ***Improved underperformance detection and reduction of false alarms:*** Current monitoring and diagnostics software can detect large power excursions. However, they often require manual review of the excursion to determine if the excursion is real – versus being a false alarm – and then identify its possible cause. Initial application of machine learning is promising for reducing false alarms and detecting more subtle underperformance events. EPRI was recently selected by the U.S. Department of Energy's Solar Energy Technologies Office to receive a $2.5M award to continue this research and develop additional capabilities that can automate the diagnosis of the cause of the underperformance.

- ***Degradation benchmarking:***

  Historical knowledge of how the power of PV modules declines over time – i.e., degrades – is based primarily on single modules in isolation or small test arrays. Very little is currently known about how large-scale plants degrade. EPRI is collecting existing large-scale PV plant performance data and using new degradation calculation methodologies that are well-suited for broad application across many PV plants. This benchmarking initiative, which is part of EPRI's Solar Owner's League, aims to quantify the extent of PV plant degradation, compare performance across multiple fleets, and begin analyzing reasons behind varied degradation rates.



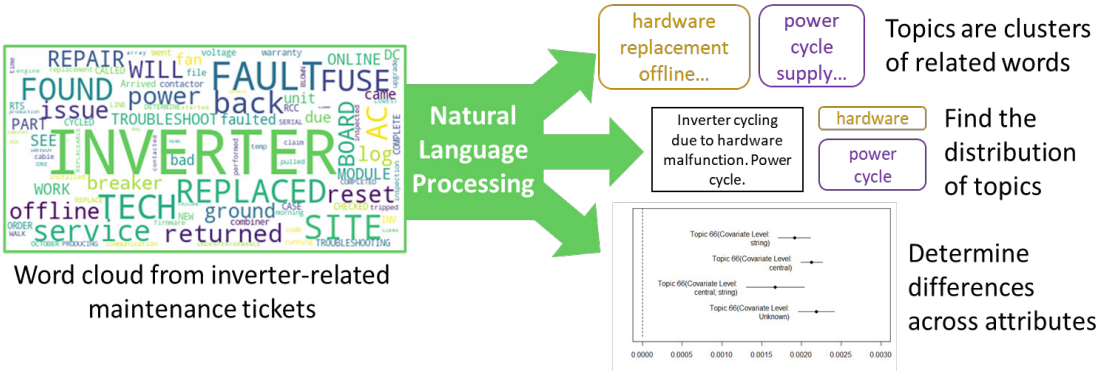
Machine learning is promising for detecting subtle underperformance in PV plants compared to more commonly used methods.

Improving PV Maintenance

Currently, many PV plant owners/operators are performing preventative maintenance (PM) to maintain equipment warranties from the original equipment manufacturer (OEM). It is not readily apparent if or how the OEM's recommended activities and frequency align with the plant owners'/operators' availability and uptime goals. Knowing the link between maintenance activity, frequency, and availability is particularly important when the warranty term expires and/or if the OEM exits the market. ***EPRI is currently applying tried-and-true methodologies and novel data-driven approaches to optimize PV plant maintenance.***

Inverters are commonly the source of most maintenance tickets in PV plants, most often being corrective maintenance in response to some event. Initial results indicate that the few PM activities currently recommended by most OEMs are effective at preventing the particular failures for which their intended. However, there are other common failures not addressed by existing PM activities, which indicates opportunity for improvement that may increase availability and reduced unplanned, reactive maintenance.

More research is needed to identify the reason behind the events and develop mitigation strategies. Natural language processing methods are being applied to the maintenance tickets to extract information about the inverter failures and root causes. Then, additional machine learning techniques are being used to search for correlations that could be used to improve maintenance activities and frequency. For example, linking a spike in springtime fan failures at plants located in temperate climates to pollen build-up in the filters and changing maintenance timing and frequency accordingly.



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2. *Application of Machine Learning to Large-scale PV Plant Faults and Failures.* EPRI, Palo Alto, CA: 2019. 3002013671.

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