PV Inverter Availability from the US PV Fleet

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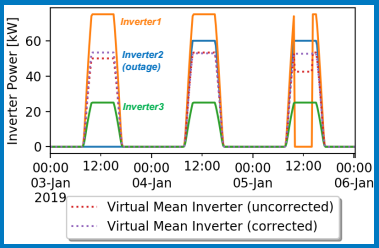
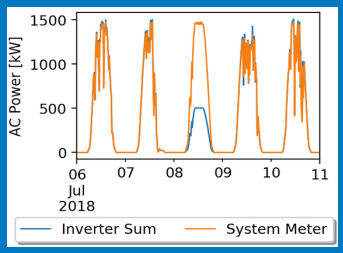
ABSTRACT: PV availability considers all elements (tracker, inverter, site transformer, etc.) of the system but the inverter is the largest contributor. Availability is an important metric for production guarantees and financial targets for new systems. Historically, system availability has been quoted at 99% available, but field validation has been sparse.

In the PV Fleet Performance Data Initiative, we partner with photovoltaic (PV) fleet owners to collect time-series PV production data, and publish aggregated, anonymized results. An assessment of inverter availability is conducted on 1128 systems which passed our data quality checks, showing a range of P50 inverter availability of 0.985-0.995. A collaboration with DNV who provides due diligence for solar energy projects, using different system data and different methodology has arrived at similar results: System capacity, inverter size and years of age are major determinants of inverter availability.

NREL METHOD: INVERTER AVAILABILITY DETECTION FROM TIME-SERIES DATA



Example for estimating system power if all inverters were online. Nearest neighbors fill in expected energy during inverter outage.

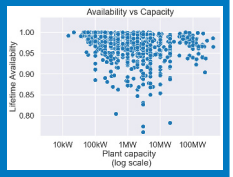


Example partial communication outage where some inverters aren't communicating. Comparison with system meter provides 'true' value. Total communication outage (not shown) requires cumulative meter energy data [K. Anderson 2020]

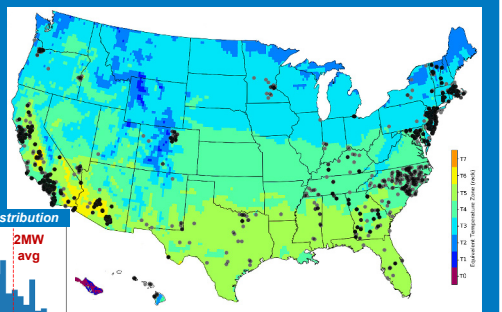
DNV METHOD: MONTHLY OPERATING REPORTS

Monthly availability data

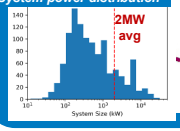
- From DNV clients & industry partners
- 1100+ unique N. America systems, 56k+ project-months
- 14+ GW installed capacity ranging from 10kW – 400MW
- Mostly based on operator-reported monthly aggregates. Some based on SCADA analysis



SITES INVESTIGATED FOR NREL ANALYSIS

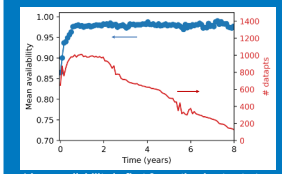


System power distribution



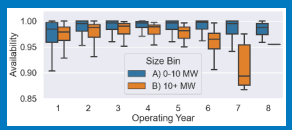
INVERTER AVAILABILITY OVER TIME

NREL Availability by system age

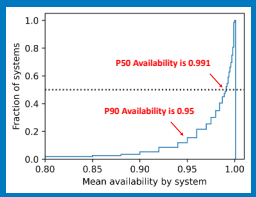


* Low availability in first 6 months due to start-up

DNV Availability by system age

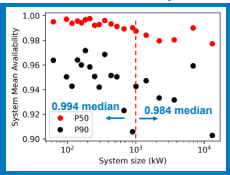


- "Teething" issues in first 6 months; recovery by Yr 2
- Drop-off in years 6+ is unexpected, possibly due to low sample count (N < 16)



NREL: Overall CDF of mean system availability showing 0.99 Median and 0.95 P90 value

NREL: System availability decreases with system size

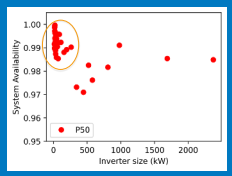


DNV: System availability decreases with system size

	<10MW	>=10 MW
Count*	915	72
P50	98.8%	98.0%
P90	94.5%	93.3%
P99	84.9%	78.5%

*Only systems with 24+ months of data

NREL - AVAILABILITY VS INVERTER SIZE



* t-test for <200kW vs >200kW inverters: p=2e-8

Smaller inverters < 250kW have a cluster of median availability ~0.99.

Larger inverters median availability ~0.98.

Central inverters typically include combiner boxes and additional points of failure. An outage has higher relative impact with fewer inverters per system.

CONCLUSIONS

- Overall inverter availability is low in the first 6 months of system performance before reaching steady-state by the end of the first year.
- System-level aggregated data shows a median (P50) system availability of 0.99, and a lower P90 value of 0.95.
- A dependence on system size is also identified, with better inverter availability results for smaller PV systems.
- Potential causes of this effect may include the selection of inverter itself: smaller inverters 6kW-250kW showed better average availability than inverters 300kW-5MW.
- The elimination of string combiner boxes and lower energy impact when one particular inverter goes off-line are potential benefits of a string inverter-based PV system architecture.
- DNV also analyzed availability data from over 1100 operating systems and found similar trends.
- DNV's P50 industry guidance on expected availability has been updated to reflect the data and the following observations: utility scale systems have lower availability than DG systems, availability is lower in first year compared to subsequent years, and that actual availability has been lower than previously expected.

Link here to download the full NREL report : *"Availability and performance loss factors for US PV Fleet systems" NREL/TP-5K00-88769*

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Photovoltaic Reliability Workshop (PVRW)
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Link here for the DNV / NREL / kWhAnalytics webinar: *"Are solar availability assumptions too optimistic?"*