Diagnostic Techniques for Solar PV Plant Performance

Jay Miller, P.E. | Black & Veatch (www.bv.com)

Time series comparison of plant and total inverter power

Uses

- Distinguish between inverter loss of output and loss of communications.
- Demonstrate inverter availability in the absence of reported output.

Calculate for each time interval:

$$A = \sum I_i \ , \ \text{AP ratio} = {}^{A}/_{P}$$

where: I is reported output power for each inverter i, (kW)

P is measured plant output power (kW)

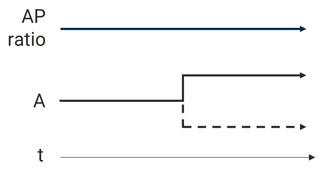
The AP ratio is expected to be greater than 1.0, owing to network and transformation losses. If it isn't, there are likely one or more inverters that are exporting power but not communicating.

Application

Examine the time series of A and AP ratio, looking for simultaneous shifts:

<u>Case A</u>

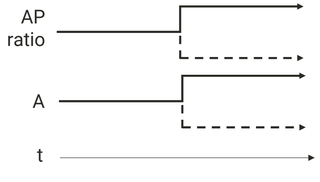
A shifts up or down **without** corresponding shift in AP ratio



One or more inverters has **started or stopped exporting power**.

<u>Case B</u>

A and AP ratio shift up or down **together**



One or more inverters has **started or stopped communicating** but is still exporting power.

Limitations

Inverter reported output power is generally less accurate than plant power output, and less so at lower power levels.

Assertions of inverter availability without communications may require further documentation e.g., photos of the inverter HMI.

Measured vs. expected PV array power

- Identify sub-arrays with reduced capacity e.g., from isolated strings.
- Detect periods of mutual shading.

Scatter plot for each inverter DC feeder:

Measured power (kWdc) $= I \times V$

where: I is reported feeder current (kA)

V is reported DC bus voltage (Vdc)

Expected power (kWdc) $= P_{max} \times TPOA / G_C \times C_T$

where: P_{max} is the nominal capacity of the sub-array (kWp)

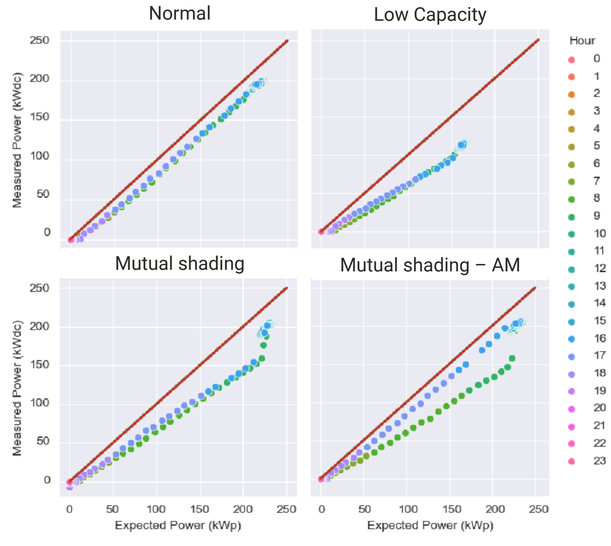
TPOA is the total plane-of-array irradiance (W/m^2)

Gc = 1000 W/m^2

$C_T = 1 - \gamma * (25°C - T_{Cell})^{\dagger}$

and γ is the temperature coefficient of power (%/°C)

T_{cell} is the measured cell temperature (°C)‡



Normal response should be determined by comparison across as large of a set of DC feeders as practicable.

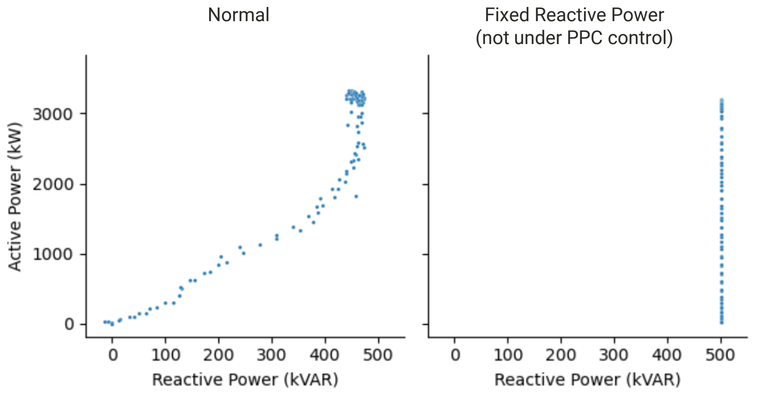
Clear conditions provide the best opportunity for diagnosis.

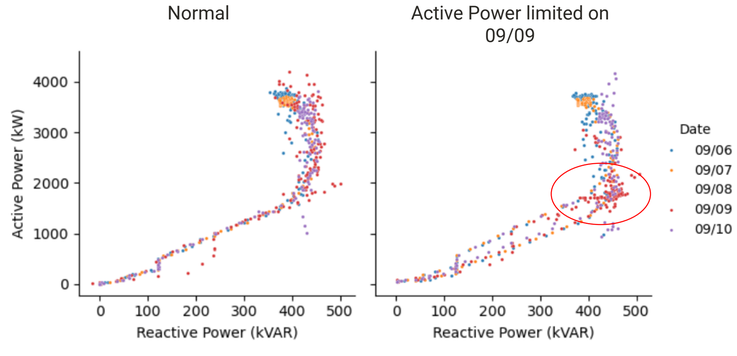
Inverter P-Q plot

- Identify inverters that are not responding to PPC control.
- Detect occurrences of active power limitation.

For each inverter or sub-inverter, scatter plot AC active power(y-axis) vs AC reactive power (x-axis) for a single day's operation.

Look for deviations from the normal pattern:





Acknowledgements

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Plots were produced using Jupyter Notebook and the Seaborn library.

References

† Dierauf, T. et al. (2013) Weather-Corrected Performance Ratio. ‡ King, D. L., Boyson, W. E., & Kratochvil, J. A. (2004). Photovoltaic Array Performance Model (SAND2004-3535). Sandia National Laboratories, Albuquerque, NM.