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Modeling Efficiency of Inverters with Multiple Inputs

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Abstract

- Many inverters offer multiple, independent maximum power point trackers (MPPTs) to accommodate photovoltaic arrays with different orientations or capacities.
- No validated model for overall DC-to-AC power conversion efficiency is available for such inverters.
- We propose a mathematical model for the efficiency of a multi-MPPT inverter and present validation using a commercial inverter with six MPPT inputs.

Background

- Available inverter models [1], [2], [3] describe inverter efficiency as a function of total input DC power and DC voltage.
- These models were developed and validated for inverters with a single maximum power point tracker.
- Parameters are fitted to observed conversion efficiency curves.
- These models are being fit to inverters with multiple inputs.
- Measurements are done with all inputs held at equal voltage and DC power.

Single Input Inverter Model

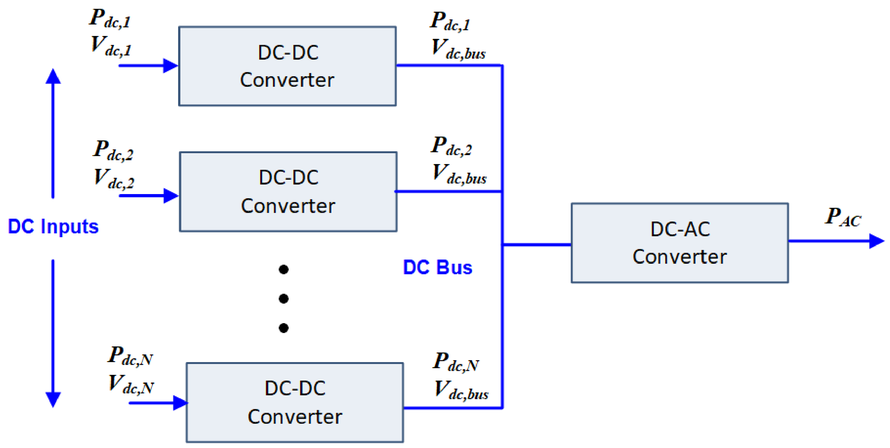
$$P_{AC} = min\left\{f\left(P_{DC}, V_{DC}\right), P_{AC,max}\right\}$$

Inverter model function

Total input DC power

DC input voltage
Assumed equal on all inputs

Multiple-input Inverter Model



Block Diagram of a Multi-Channel PV Inverter

$$P_{DC} = \sum_{i=1}^{N} P_{dc,i}$$

DC power on each input

Total input DC power

DC voltage on each input

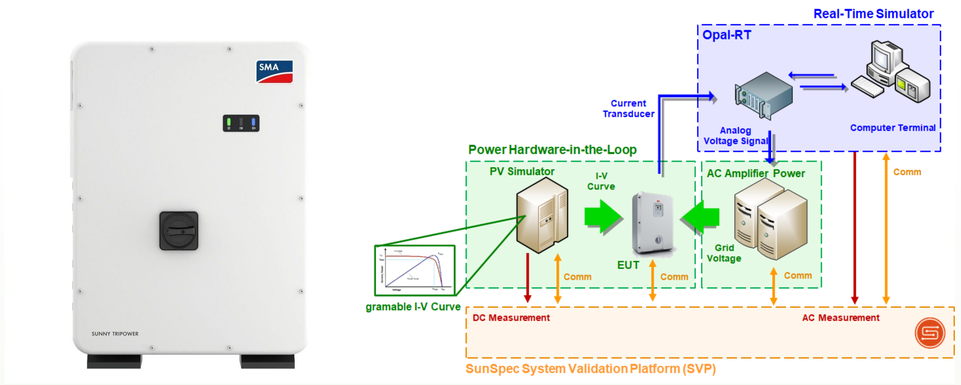
$$P_{AC} = min\left\{\sum_{i=1}^{N} \frac{P_{dc,i}}{P_{DC}} f\left(P_{DC}, V_{dc,i}\right), P_{AC,max}\right\}$$

Assumptions

- Each DC-DC converter operates independently
- Each DC-DC converter is equally efficient

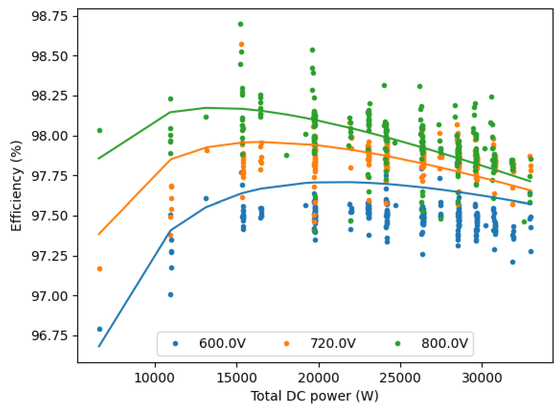
Validation

- SMA Tripower Core 1 inverter (6 independent MPPT inputs)
- Voltage and power varied at each input over test matrix; total input DC power and output AC power are measured

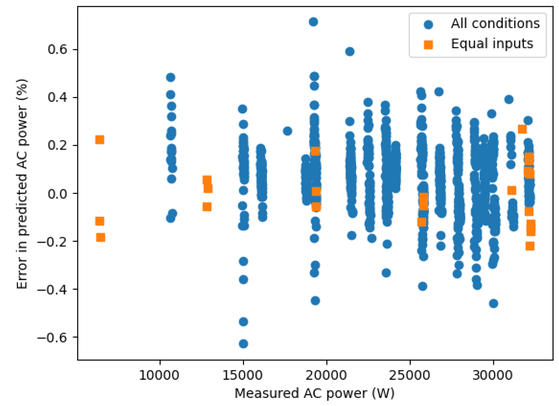


Results

- Model f is fit to the "equal voltage and power" subset of data in the same manner as for singl-input inverter models (using pvlib-python [4], `inverter.fit_sandia` function; see [5] for test procedure)
- Prediction error is similar in magnitude as for single-input inverter models



Multi-input inverter predicted (lines) and measured (points) efficiency



Error in predicted efficiency

[1] D. L. King, S. Gonzalez, G. M. Galbraith, and W. E. Boyson. "Performance Model for Grid-Connected Photovoltaic Inverters". Sandia National Laboratories Report SAND2007-5036, September 2007.

[2] A. Driesse, P. Jain and S. Harrison, "Beyond the curves: Modeling the electrical efficiency of photovoltaic inverters," 2008 33rd IEEE Photovoltaic Specialists Conference, 2008, pp. 1-6, doi: 10.1109/PVSC.2008.4922827.

[3] A. Dobos. "PVWatts Version 5 Manual". National Renewable Energy Laboratory Report NREL/TP-6A20-62641. September 2014.

[4] William F. Holmgren, Clifford W. Hansen, and Mark A. Mikofski. "pvlib python: a python package for modeling solar energy systems." Journal of Open Source Software, 3(29), 884, (2018). https://doi.org/10.21105/joss.00884

[5] W. Bower, C. Whitaker, W. Erdman, M. Behnke, M. Fitzgerald. "Performance Test Protocol for Evaluating Inverters Used in Grid-Connected Photovoltaic Systems". Available at https://www.energy.ca.gov/sites/default/files/2020-06/2004-11-22_Sandia_Test_Protocol_ada.pdf

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