Distribution Function Instead of Steady-State Assumption in Time-Series Simulation

Andy Walker, PhD PE, Senior Research Fellow, National Renewable Energy Laboratory  
Jal Desai, CEM, Researcher, National Renewable Energy Laboratory

The Problem

"Quasi-steady-state assumption" assumes constant power level over time-step which is inadequate to model:
- Phenomenon of interest to grid integration such as inverter clipping and energy export
- Phenomenon of interest to storage such as battery throughput

Possible Solutions

- High-resolution time series data (seconds)
- Machine learning or heuristics to estimate phenomenon within duration of time-step
- Distribution function to model power levels varying within duration of time-step

Distribution Function

\[ P_{t+1} = \max(P_{\text{min}} + (P_{\text{max}} - P_{\text{min}}) \cdot (1 - \left\lfloor \frac{t}{T} \right\rfloor), P_{\text{min}}) \]

Rapidly Changing Conditions

Progress to Date

- Derived form of distribution function based on first law of thermodynamics and definition of capacity factor [2]
- Determined parameters of distribution function based on clear sky model
- Validated for Quillayute, Washington; Athens, Georgia; and Daggett, California climate data [4]
- Piloted hourly simulation in MS Excel to demonstrate transparent calculations [3]
- Licensed and implemented in HOMER Pro Version 3.14.5 and higher [4]
- Coded Python version

Results are improved over existing methods

- Distribution function provides more accurate and useful results than existing steady-state assumption
- Error in inverter clipping estimate improved by an order of magnitude
- In the example to the right, clipping estimate using steady-state assumption is 1,030 kWh/year which is an error of 93%, and estimate using distribution function is 13,618 kWh/year, an error of 8%, compared to 1-minute value of 14,789 kWh/year.

Future Opportunities

- License in other commercial software products
- Expand to other technologies in addition to PV (wind, battery only, etc.)
- Publish Python version on GitHub or as an API

References