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Scenario creation and power-conditioning strategies for operating power grids with two-stage stochastic economic dispatch

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Background

- Two-stage stochastic economic dispatch, coupled with multiperiod high-fidelity scenarios, were used to simulate power grid operations.
- Wind farms simulated via collections of WIND Toolkit sites and analog scenarios are selected from high-fidelity data sets.
- We suggest that using data-driven scenarios is a viable alternative to generating scenarios via statistical means.

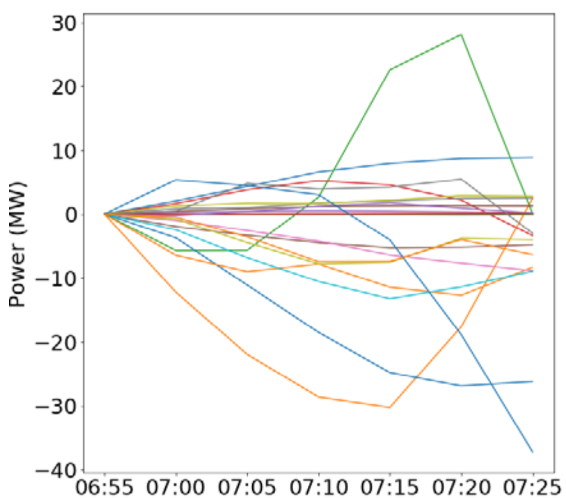
$$
\begin{aligned}
\min_{\boldsymbol{x}} \quad & f(\boldsymbol{x}) + \mathbb{E}_{\boldsymbol{\xi}}\left[L(\boldsymbol{x}, \boldsymbol{\xi})\right] \\
\text{s. t.} \quad & \boldsymbol{g}(\boldsymbol{x}) \leq \mathbf{0} \\
L(\boldsymbol{x}, \boldsymbol{\xi}) = \min_{\boldsymbol{y}} \quad & l(\boldsymbol{x}, \boldsymbol{y}, \boldsymbol{\xi}) \\
\text{s. t.} \quad & \boldsymbol{g}_{\boldsymbol{\xi}}(\boldsymbol{x}, \boldsymbol{y}) \leq \mathbf{0}
\end{aligned}
$$

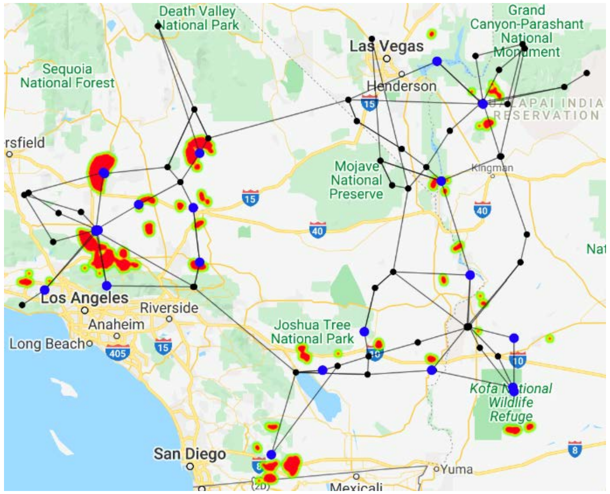
1st stage variables:
- generator set points

1st stage constraints:
- generation constraints
- ramping constraints

2nd stage variables:
- wind power dispatched
- wind power spilled
- overload and loss of load

2nd stage constraints:
- wind power balance
- power balance constraints
- DCOPF constraints





(Left) 22 wind power timeseries, composing 1 scenario, from RTS-GMLC. (Right) RTS-GMLC with WIND Toolkit-simulated wind farms (heat map), lines and buses (black points and lines) and buses with wind farms (blue points).

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Results

Experiment:
We tested our economic dispatch approach on a modified RTS-GMLC over the course of a week.

Renewable generation replaced by data from the WIND Toolkit

WIND Toolkit data split into 2 sets: actuals and scenarios dictionary.

Results:
Our approach can be cheaper in terms of total cost.

1st stage costs are slightly more expensive, 2nd stage cheaper.

Strategic over-generation: our algorithm takes on some overload to prevent loss-of-load

TABLE I: Single Period Economic Dispatch Costs

	Single Period Dispatch Costs ($)		
# of Scenarios	1st stage	2nd stage	Total Costs
deterministic	3.138×10^6	1.455×10^7	1.769×10^7
20	3.181×10^6	8.813×10^5	4.062×10^6
40	3.190×10^6	4.714×10^5	3.661×10^6
80	3.201×10^6	1.976×10^5	3.399×10^6

TABLE II: Multi-Period Economic Dispatch Costs

	Multiple Period Dispatch Costs ($)		
# of Scenarios	1st stage	2nd stage	Total Costs
deterministic	3.138×10^6	1.455×10^7	1.769×10^7
20	3.180×10^6	8.083×10^5	3.988×10^6
40	3.189×10^6	4.072×10^5	3.596×10^6
80	3.198×10^6	1.543×10^5	3.3523×10^6

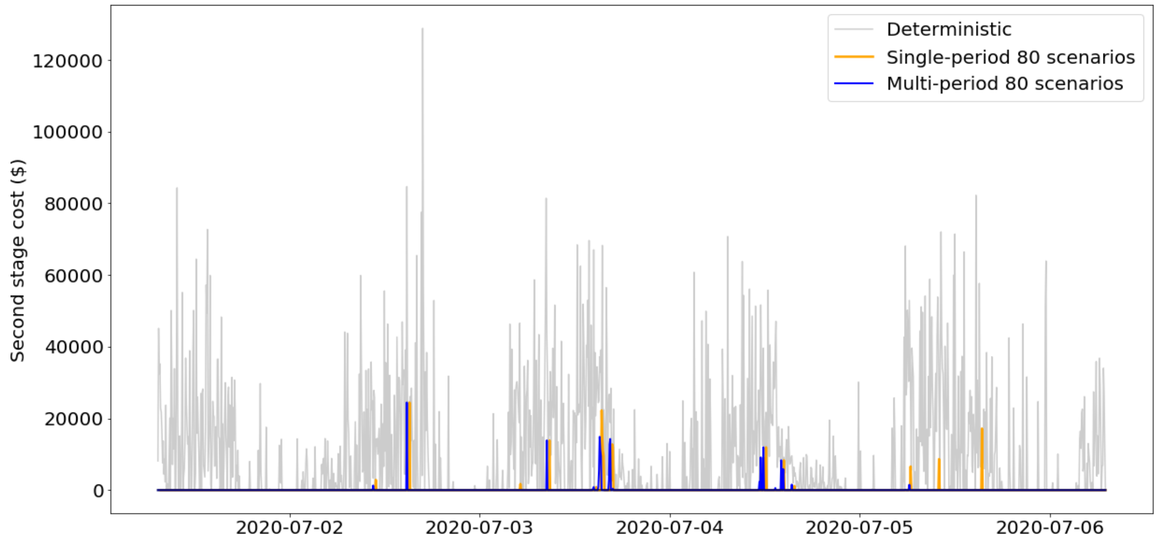
Results

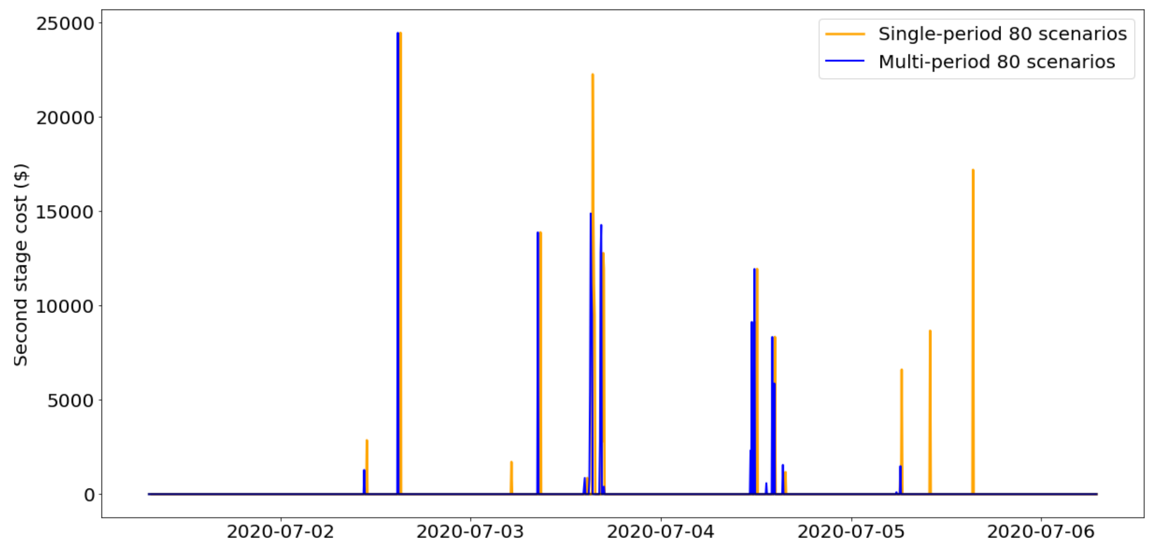
Results (continued):
(Above) Comparing 2nd stage costs between deterministic operations (persistence forecast) and single- & multi-period SED.

SED approaches substantially reduce 2nd stage costs.

(Below) Comparing only single- & multi-period SED.

Multi-period SED yielded slightly cheaper second stage costs.





Conclusions/Recommendations

- We have demonstrated that coupling stochastic programming with scenarios drawn from high-fidelity synthetic data sets yields an effective approach to computing 5-minute economic dispatch solutions.
- Further research is required on conditioning the population of scenarios and using variance reduction techniques with data-driven scenario creation.

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