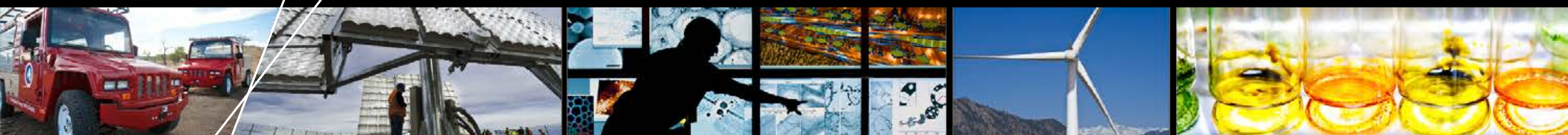
Accelerating Computation of the Unit Commitment Problem



Marissa Hummon

Team: Clayton Barrows & Wesley Jones

INFORMS 2013 Annual Meeting

Minneapolis, Minnesota

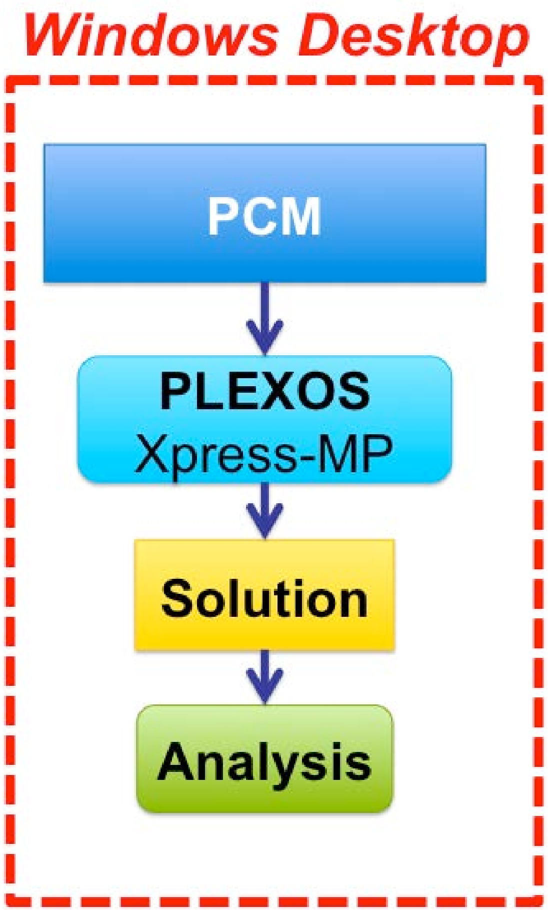
October 6-9, 2013

NREL/PR-6A20-60623

Executive Summary

Unit commitment (UC) and economic dispatch (ED) problems are the fundamental problem that system operators solve in order to minimize the costs associated with reliably operating electricity grids. We use UC/ED modeling in renewable integration studies to study the changes in system operation, emissions production, and system reliability with the addition of variable and uncertain renewable energy technologies. Simulating operations in the Eastern Interconnect for a calendar year with hourly resolution requires up to 45 days of computation. Many UC/ED studies avoid this problem by reducing the simulation horizon and/or making model simplifications (e.g. simpler network topology, consolidated generators, fewer constraints, etc.). We propose a method to decompose the inherently chronological UC/ED problem into many distinct simulation horizons for parallel computation. Decomposition enables the application of long term simulations of grid operations on high performance computation environments. This talk summarizes our foundational research on the persistence of unit commitment decisions. We demonstrate that the persistence of UC decisions are related to the operational parameters of different generators: combustion turbines (CT) operate for 1-4 hours per day to meet peak daily demand, and thus the persistence of the CT UC is about 4 hours. This talk concludes with an exploration of the uncertainty reduction enabled by allowing simulations time to recover from uninformed start conditions.

Unit commitment problem



$$\text{Min} \sum_t \sum_k c_k^t g_k^t u_k^t + sc_k^t\left(u_k^t - u_k^{t-1}\right) \quad (1)$$

s.t.

$$\sum_k g_k^t u_k^t = \sum_k l_k^t + \sum_j loss_j^u \quad \forall \text{ t} \quad (2)$$

$$\sum_k g_k^{t,MIN} u_k^t \le g_k^t \le g_k^{t,MAX} u_k^t \quad \forall \text{ t, k} \quad (3)$$

$$g_k^t - g_k^{t-1} \le ramp_k^{t,MAX} u_k^t \quad \forall \text{ t, k} \quad (4)$$

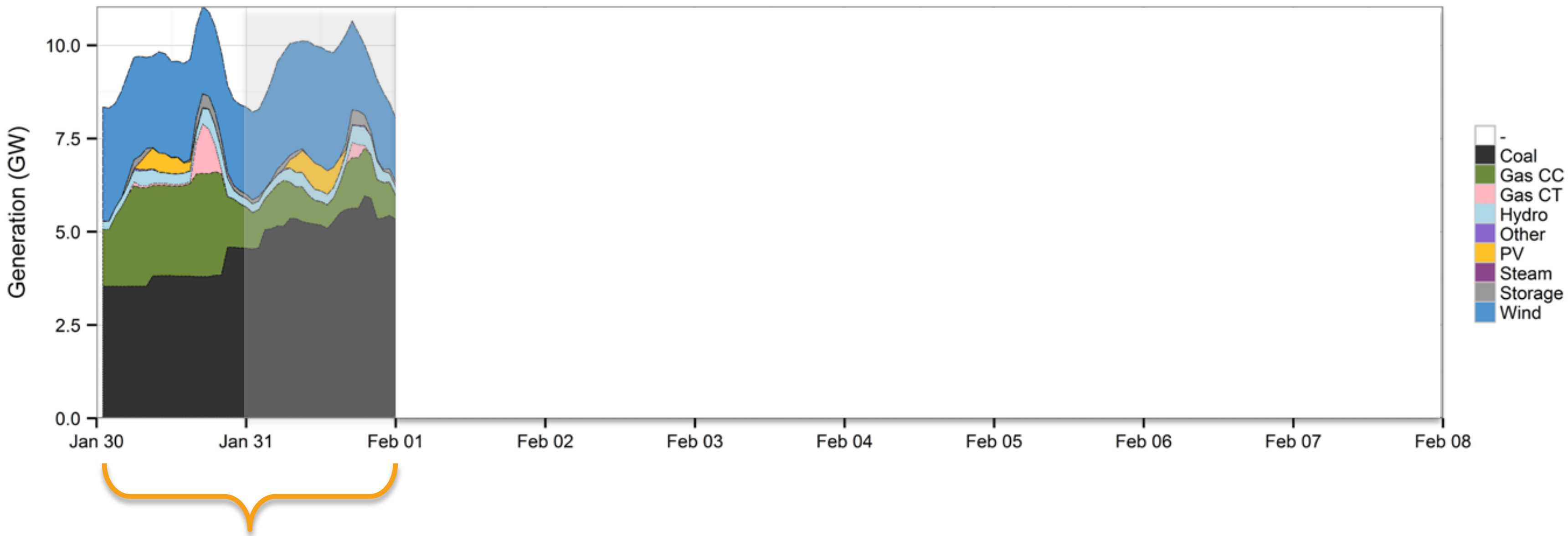
$$\sum_k g_h^t \le g_h^{day|week|month|year\_max} \quad \forall \text{ h} \quad (5)$$

$$f_j^t = \sum_k PTDF_{k,j}^s \left(g_k^t u_k^t - l_k^t\right) \quad \forall \text{ t, k, s} \quad (6)$$

$$f_j^{t,MIN} \le f_j^t \le f_j^{t,MAX} \quad \forall \text{ t} \quad (7)$$

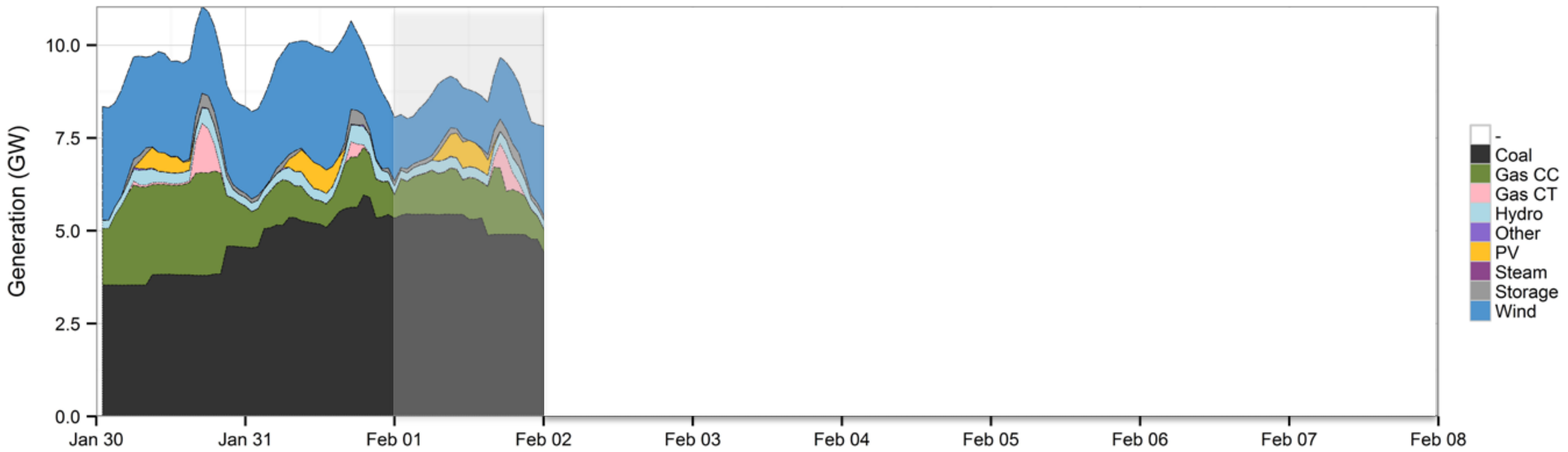
PLEXOS is a grid modeling software package from Energy Exemplar that has multiple modeling horizons including capacity expansion, unit commitment, and sub-hour dispatch. Our research focuses on parallelizing the unit commitment and economics dispatch phases.

Unit commitment and economic dispatch



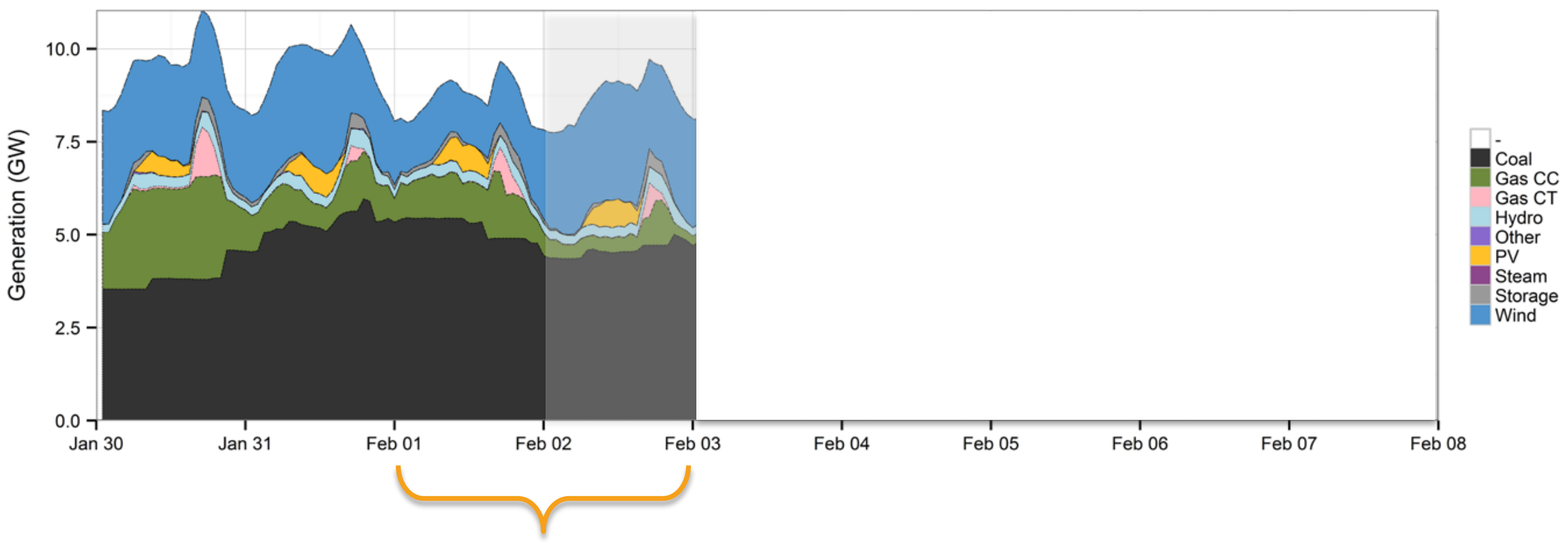
optimization horizon:
48 hours

Unit commitment and economic dispatch



rolling forward in
24 hour increments

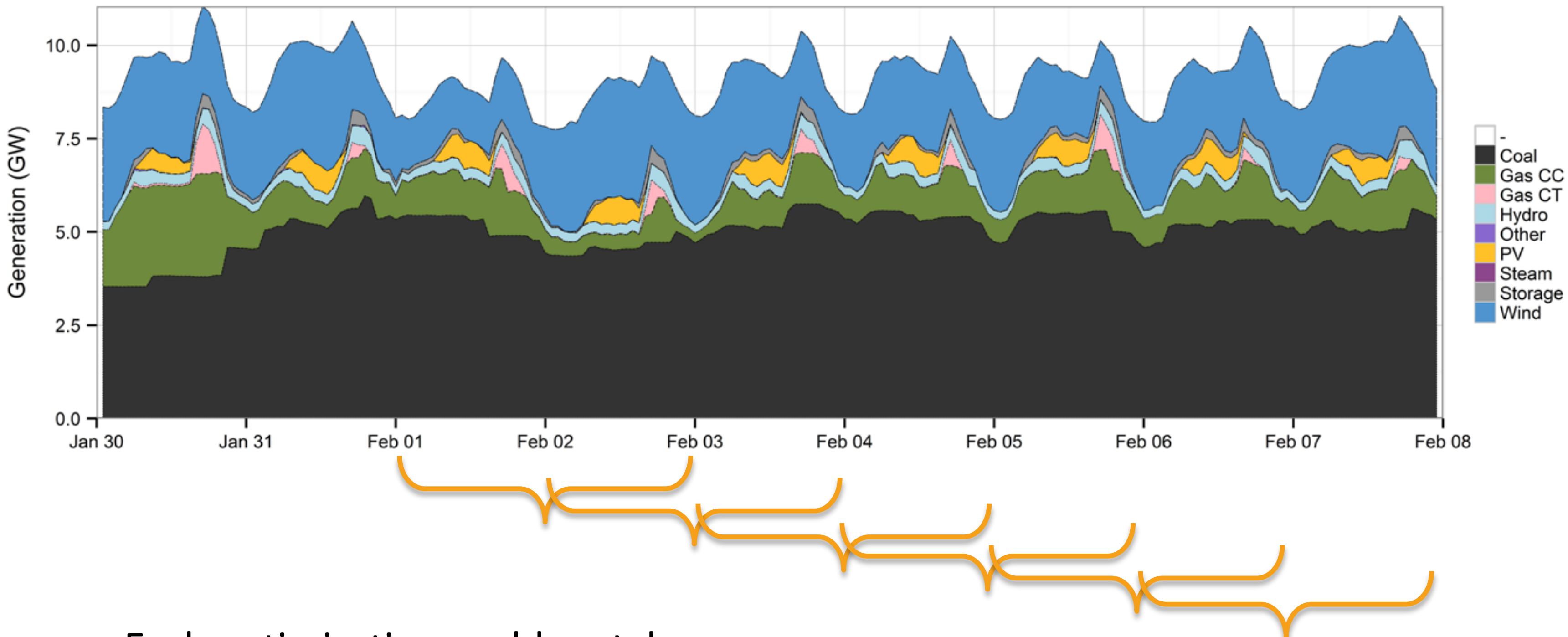
Unit commitment and economic dispatch



The state of the system at time t=0 is dependent on:

1. Generator commitment status: on/off
2. If "on": hours of continuous operation; current ramp rate
3. If "off": hours since last operation (minimum shut down duration)

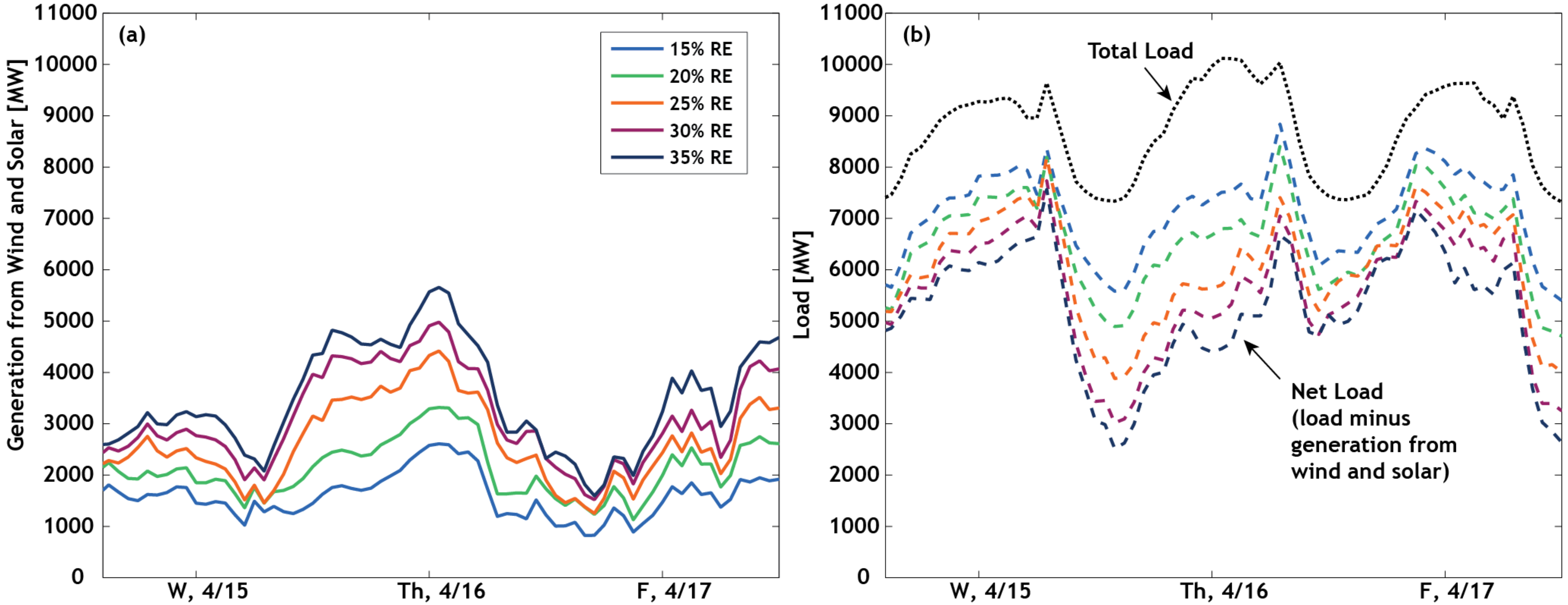
Unit commitment and economic dispatch



Each optimization problem takes between 2 and 30 minutes to solve.

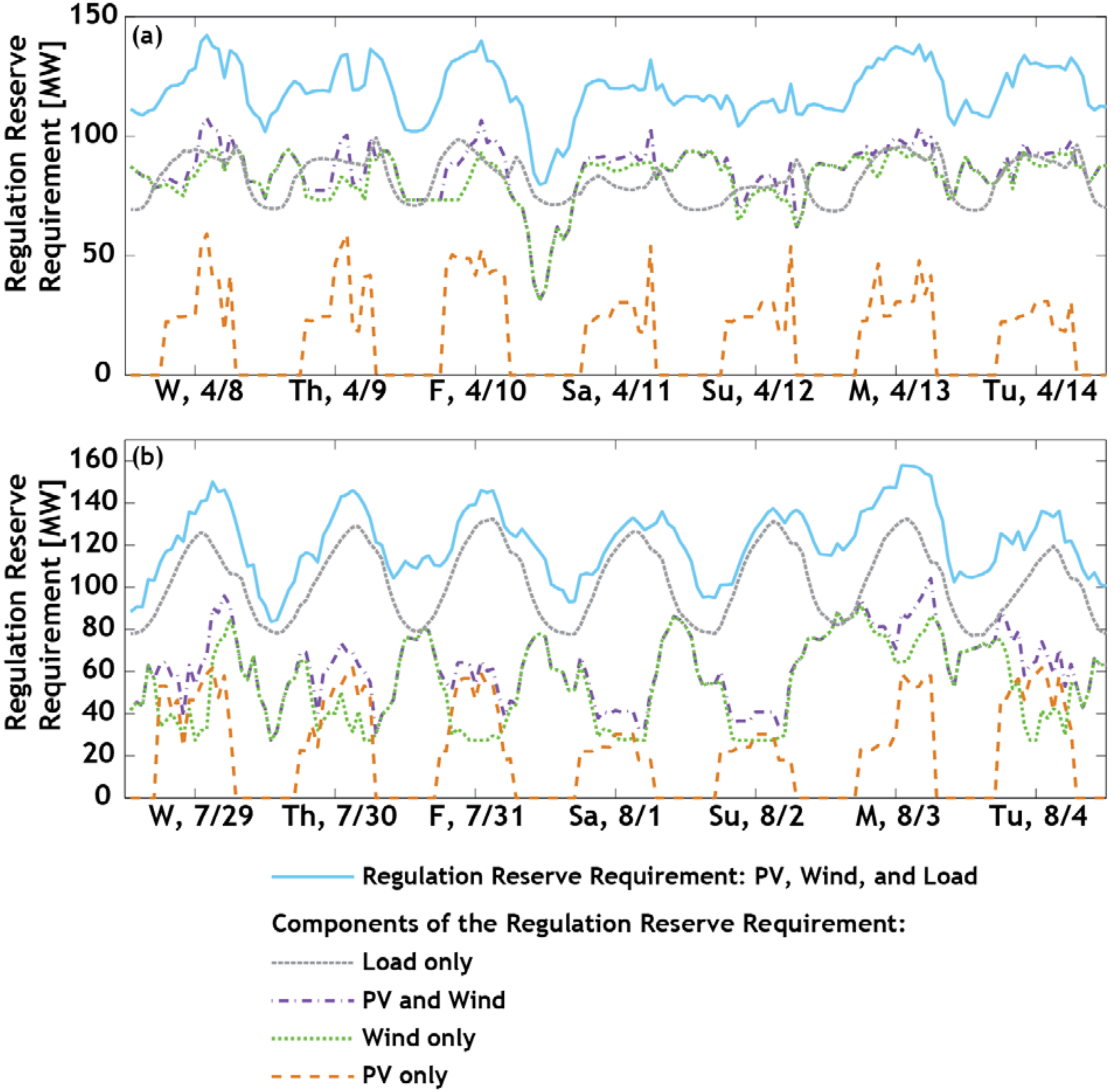
Annual solutions can range from hours to weeks.

Changes to generator configuration…



- Annual solutions are important because load and renewable generation have seasonal variations.
- Increasing renewable penetration increases the number and magnitude of short duration ramps.
- Investment decisions are based on both investment costs and long–term operational costs & savings. Production cost models are the choice tool for evaluating the majority of operational costs & savings, however they do not estimate make investment decisions.

Changes to generator configuration…



Increasing renewable penetration increases reserve requirements for the system.

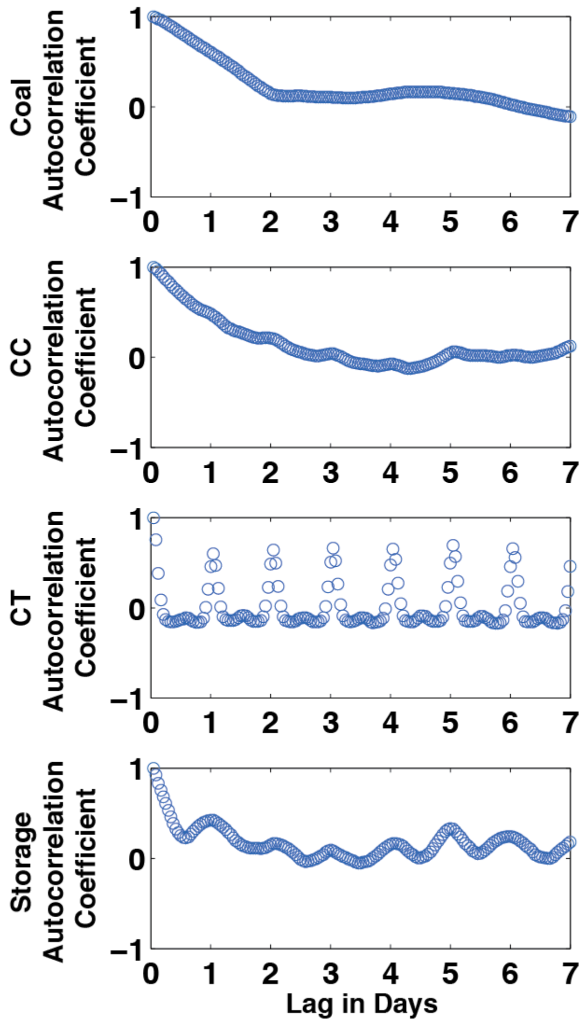
The cost of time-varying operating reserves is captured in a production cost model.

Idea: Parallelize in the time domain

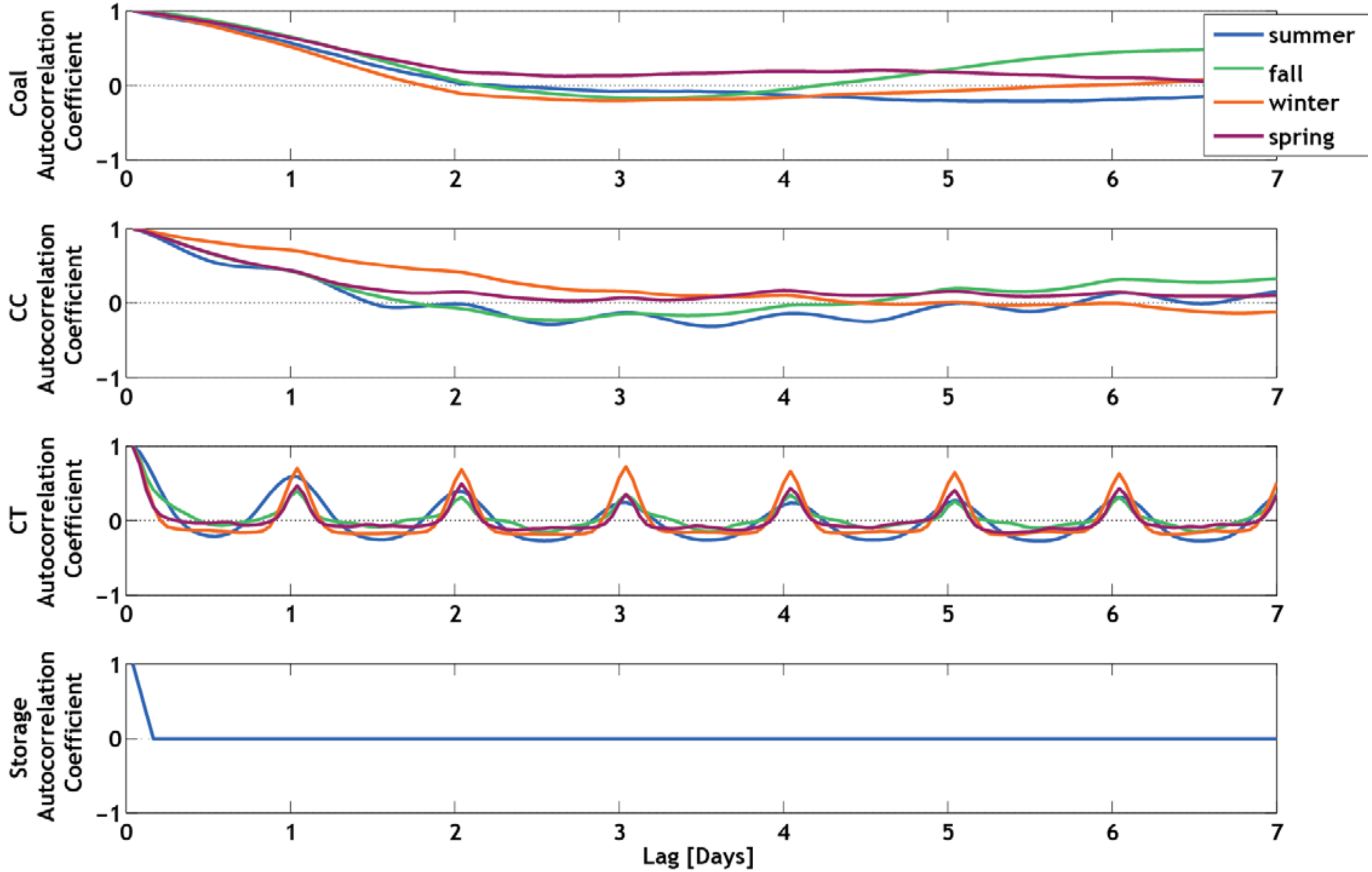
Hypothesis: a decision at time *t* is not dependent on the state of the system at previous time intervals, given a delay of *n* time periods.

Plotted here: Autocorrelation of the generator unit commitment decision variable for a group of generators.

The duration of the lag necessary for the autocorrelation of the Unit Commitment to reach a local minimum is called the Unit Commitment Decision Persistence, or just **Persistence**



UC Persistence



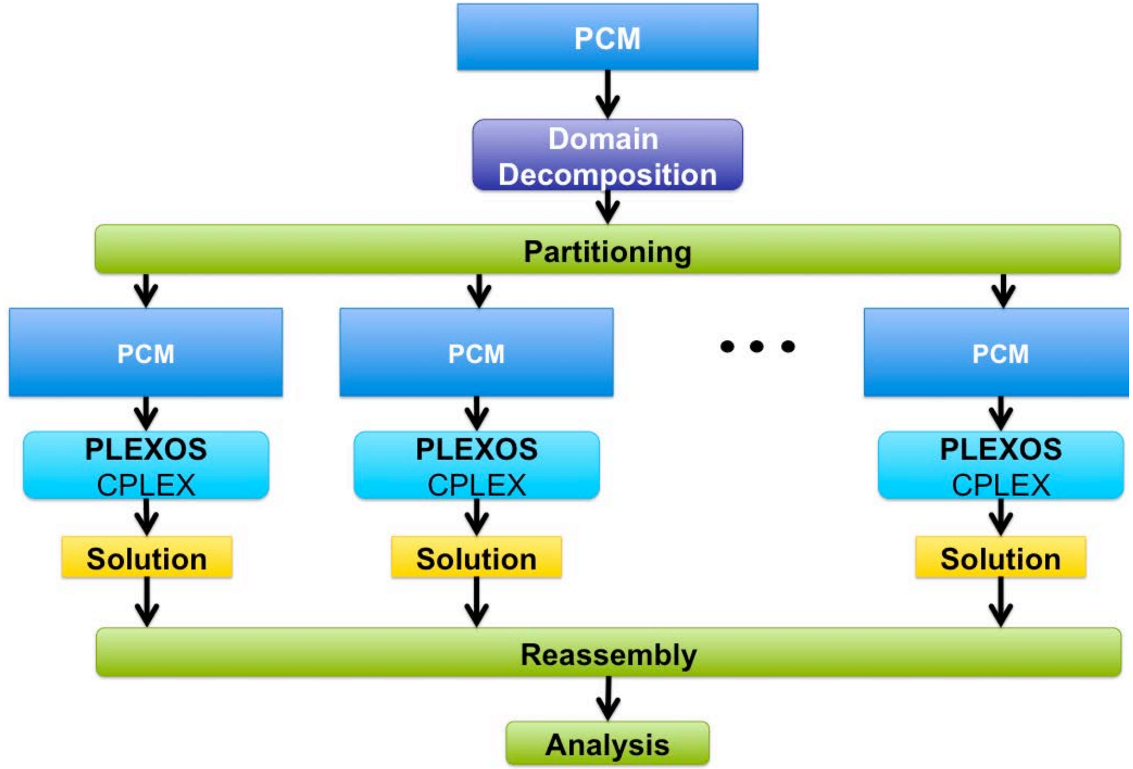
Changes with type of generator (which are distinct because of the operation restrictions: startup time, minimum up/down time, and short run marginal cost) and time of year. The “time to reach zero autocorrelation” is a measure of the how long a set of generators “hold” a UC decision.

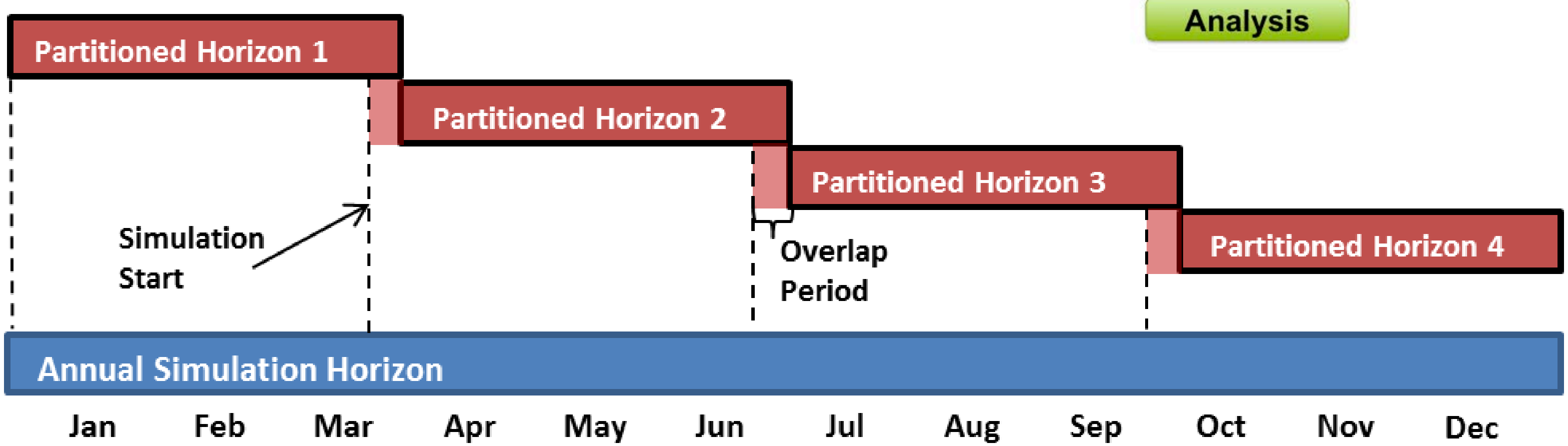
UC on NREL's HPC

NREL PIX 24580

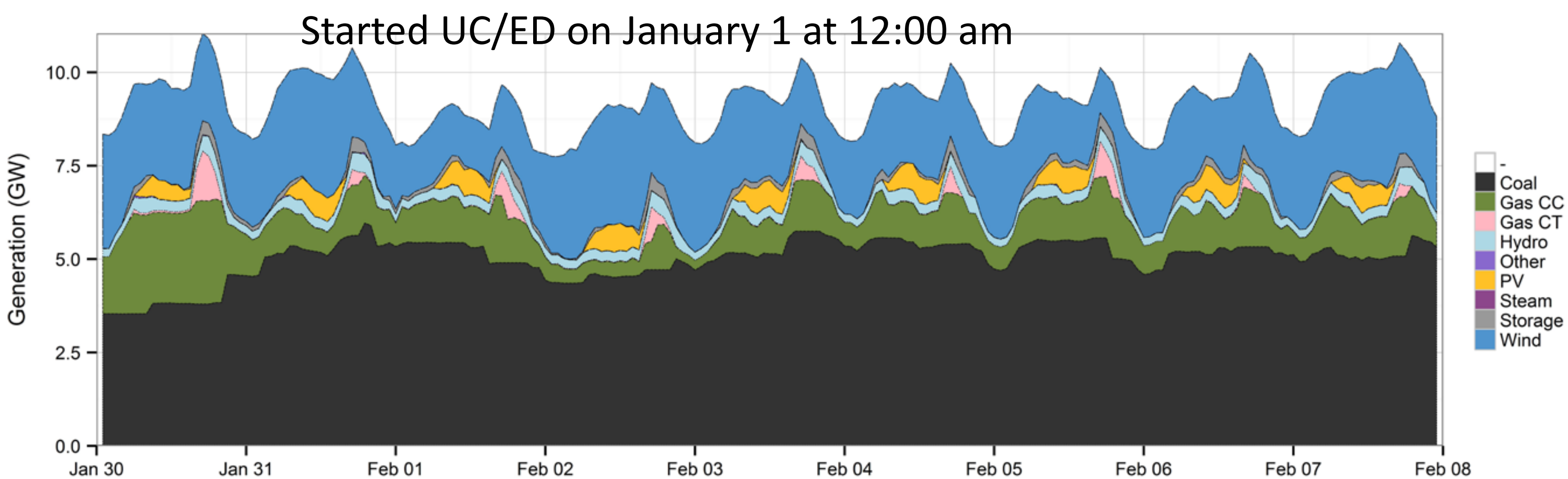
Peregrine Characteristics:

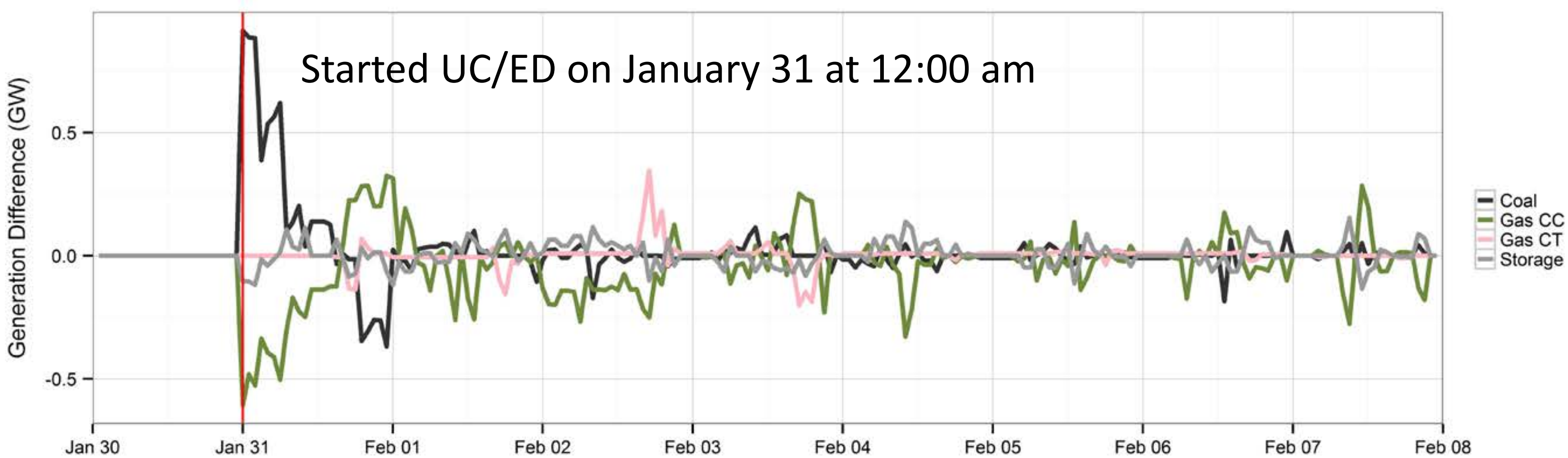
- 11520 Intel Xeon E5-2670 "SandyBridge" cores
- 14400 next-generation Intel Xeon "Ivy Bridge" core
- 576 Intel Phi Intel Many Integrated Core (MIC) core co-processors with 60+ cores each
- 32 GB DDR3 1600Mhz memory per node
- Peregrine will deliver a peak performance of 1 petaFLOPS



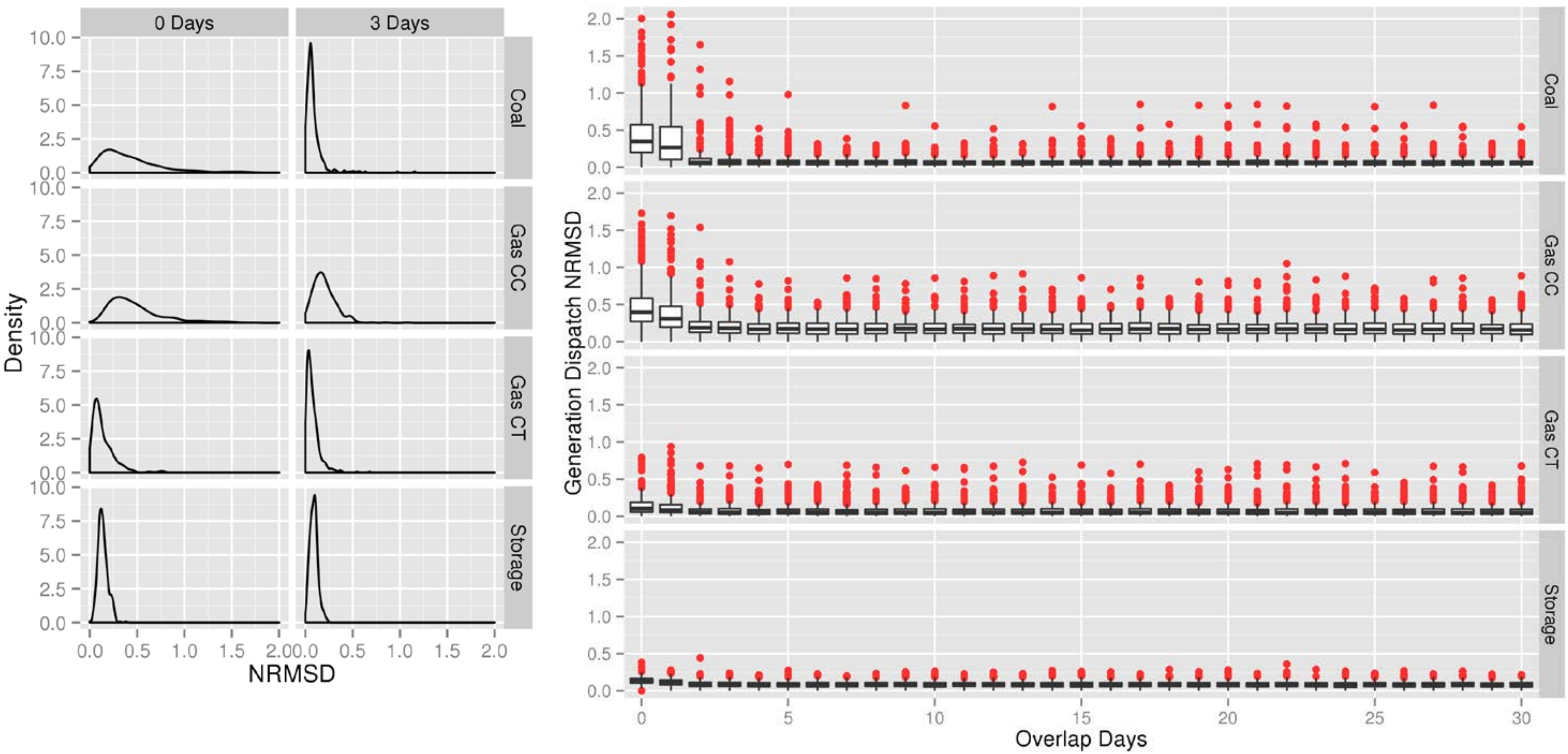


Change in UC/ED with no overlap



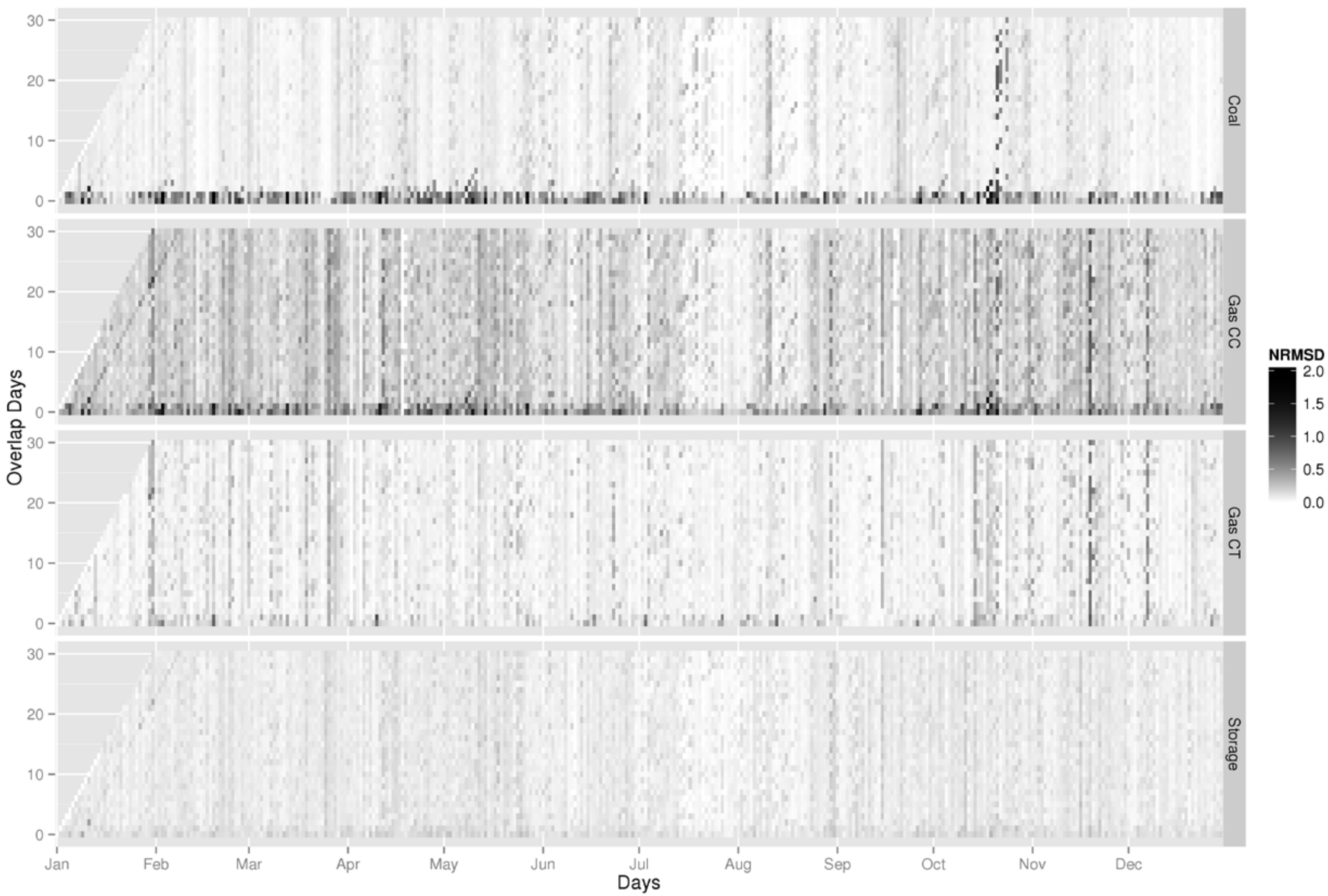


Effect of Overlap on Dispatch



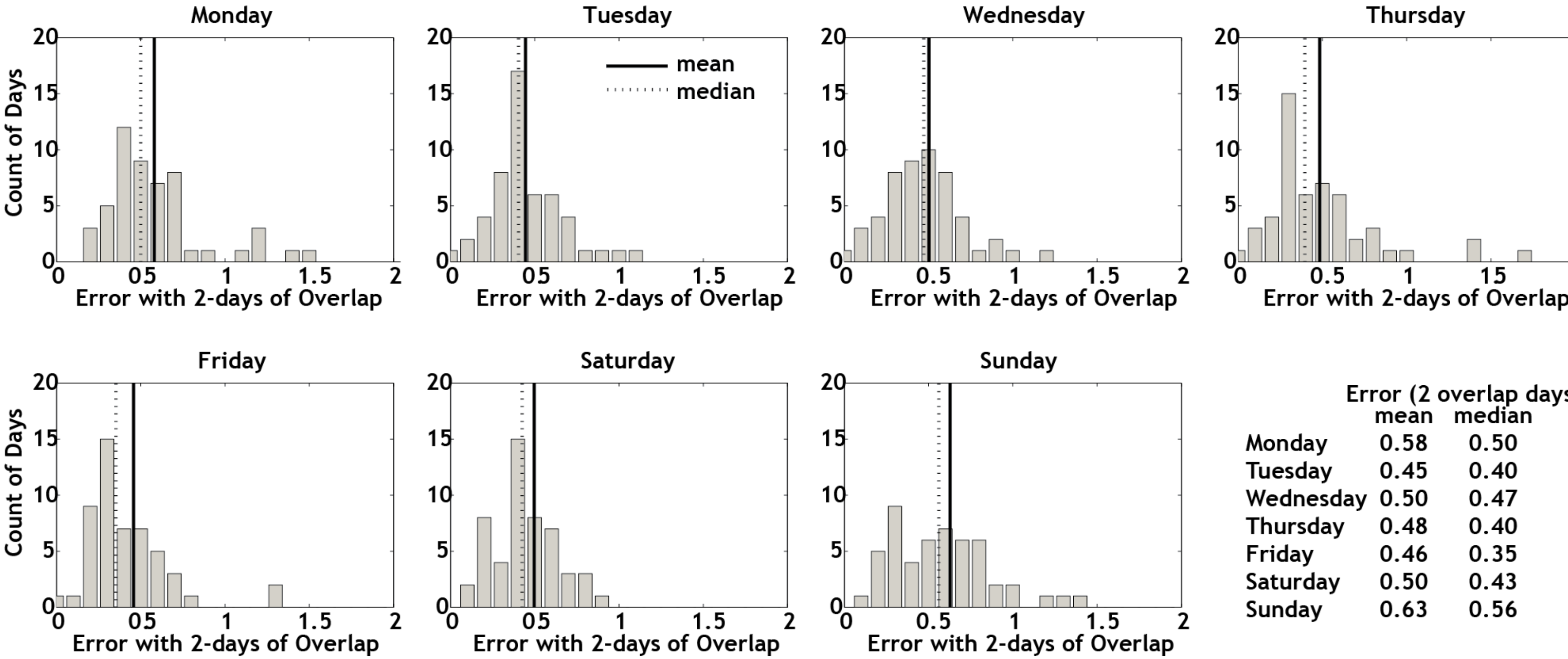
Normalized root mean square difference (NRMSD) in generation dispatch, by type of generator, relative to the annual solution. This calculation is made each day and plotted relative to the number of overlap days (number of days since the start of the optimization).

Seasonal Overlap



NRMSD decays significantly after 2-days of overlap throughout the year.

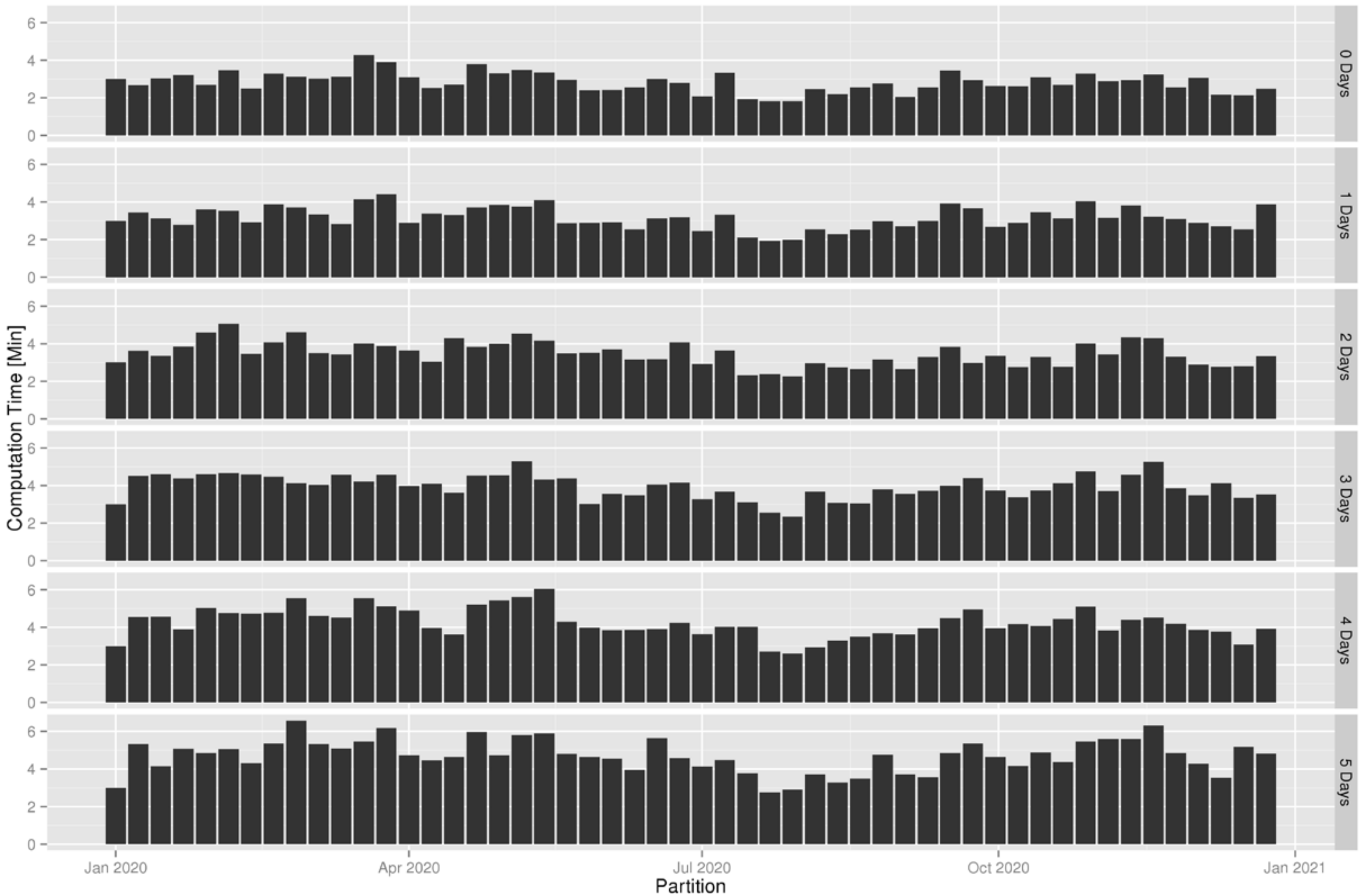
Day of Week Overlap



Error (2 overlap days)	mean	median
Monday	0.58	0.50
Tuesday	0.45	0.40
Wednesday	0.50	0.47
Thursday	0.48	0.40
Friday	0.46	0.35
Saturday	0.50	0.43
Sunday	0.63	0.56

For the Colorado test system, model start days with least NRMSD error are Sunday and Wednesday, corresponding to taking the data on Tuesday and Friday, respectively, with a 2-day overlap.

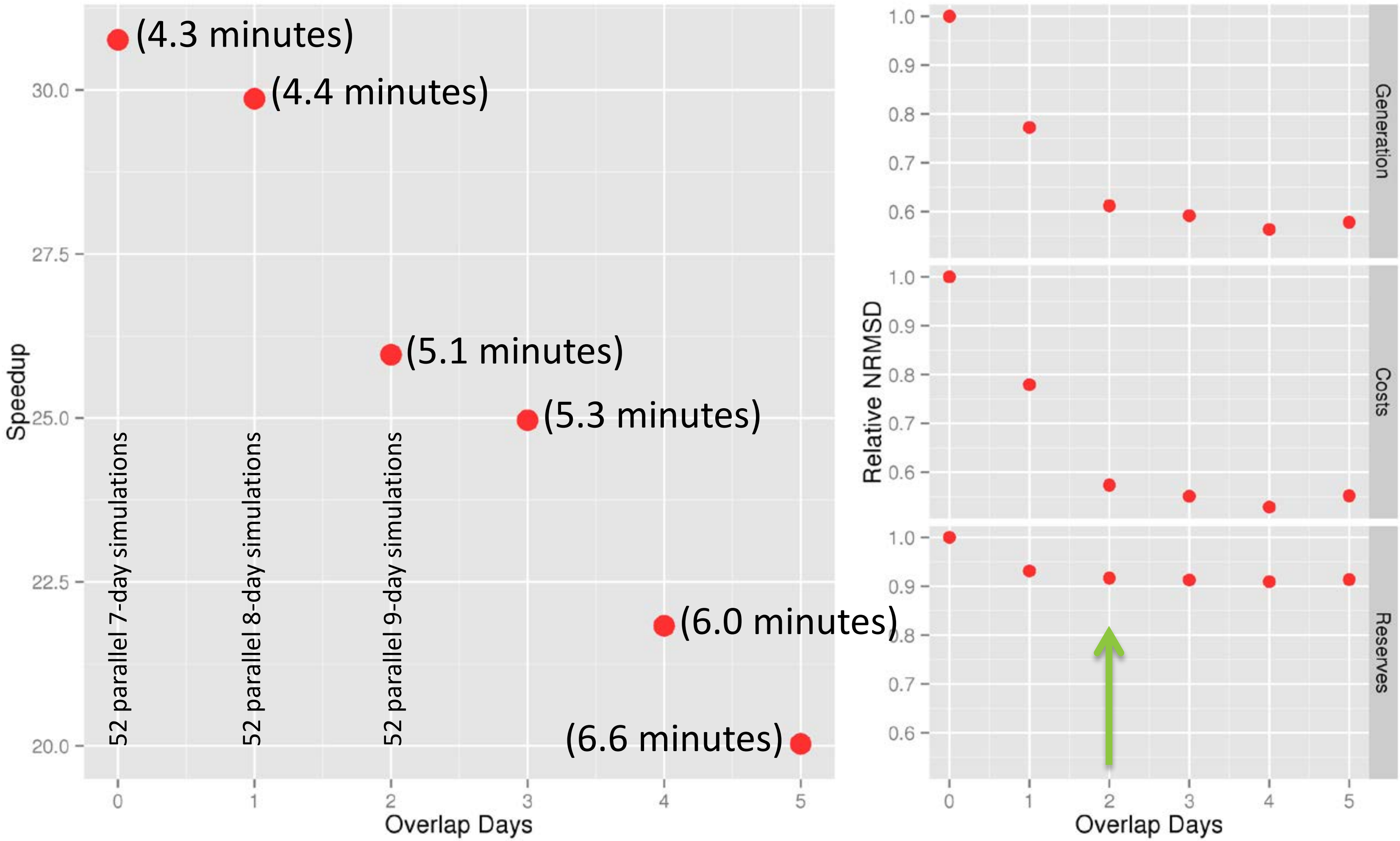
ST Solution Time



9-day simulations: weekly with 2-days of overlap.

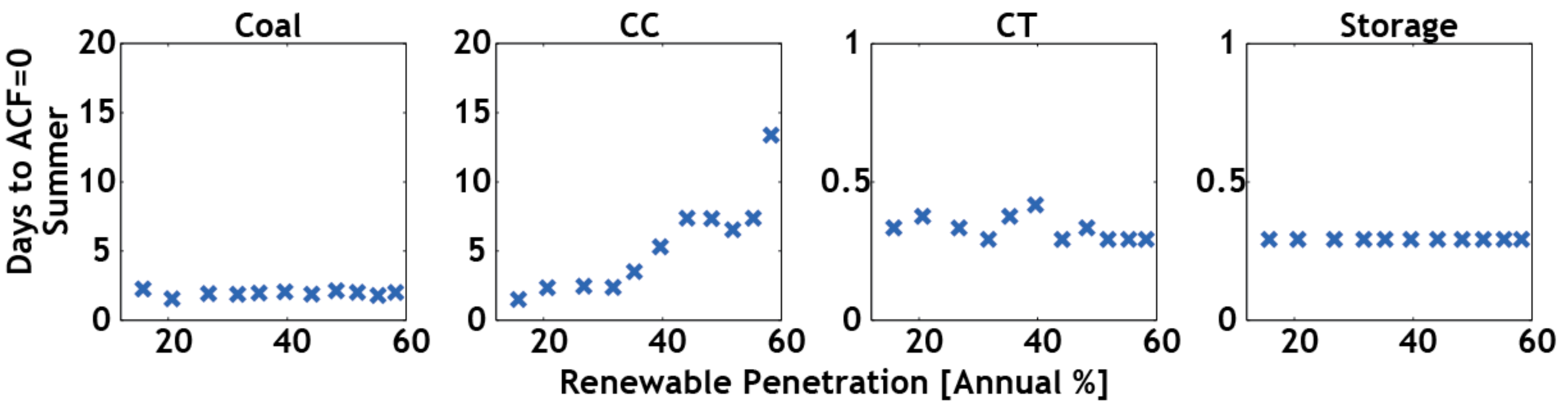
Speedup in hourly UC simulation

Annual solution takes 131.7 minutes.
With 52 partitions (with increasing overlap days):



Future Work

- **Explore overlap on different systems**



- **Seed UC partitions with a "guess" at the commitment state variable in order to decrease overlap period**
- **Explore overlap on hour-ahead and 5-minute dispatch models**

Thanks and Questions?

Marissa Hummon

303-275-3269

Marissa.hummon@nrel.gov