Scenario Generation and Reduction in Power Generation Expansion Planning

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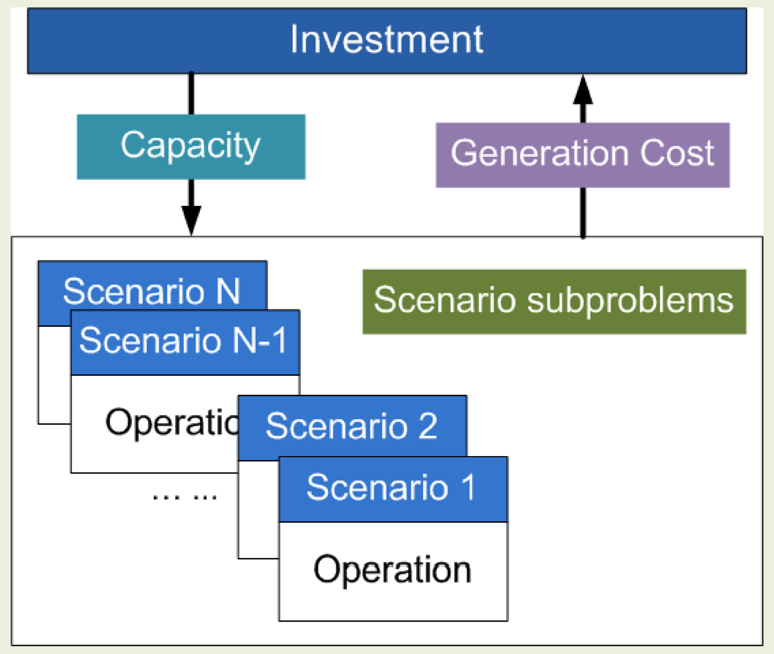
Research objectives

Develop, implement and test a method to reduce the number of scenarios considered in stochastic programming when implemented with a rolling time horizon for long-term resource planning under uncertainty:

•Alleviate the computational burden of applying scenario-based two-stage stochastic programming.
•Reduce the density of a long-term scenario tree for uncertain demand and fuel price.
•Maintain accuracy of first-stage investment decisions.



Importance for the future grid

•Need for planning tools to accommodate increasing uncertainty and the associated risks posed by high levels of renewable resource penetration, demand response, increased electrification, and climate change.
•Mitigation of computational issues that currently hinder the widespread use of these tools.

Research deliverables

•Year 1: Demonstration of scenario reduction method for generation expansion in a small system.
•Final: Comprehensive testing against other methods in realistic-sized generation expansion problems.

Generation expansion model

Minimize the sum of annualized investment cost and the expected present value of cost to satisfy load with penalty for unserved energy.

$$\min_{U_{gt}} \sum_t \sum_g \frac{b_g m_g^{max} U_{gt}}{(1+r)^{t-1}} + \sum_i p_i \xi_i \qquad \xi_i = \min_{E_{gti}, UE_{ti}} \frac{\sum_t \left(\sum_g c_{gti} E_{gti} + P_c UE_{ti}\right)}{(1+r)^{t-1}}$$

Constraints:

•Limits on numbers of added units:

$$\sum_t U_{gt} \le u_g^{max} \qquad \forall g$$

•Energy balance:

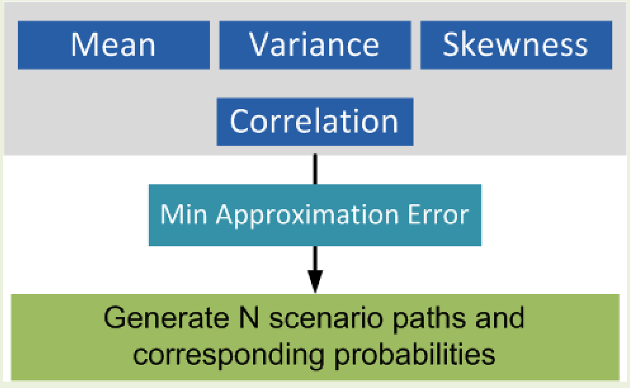
$$\sum_g E_{gti} + UE_{ti} = d_{ti} \qquad \forall t,i$$

•Capacity:

$$E_{gti} \le h_t \left(n_g^{max} \sum_{y \le Y_t} U_{gi} + I_g\right) \qquad \forall g,t,i$$

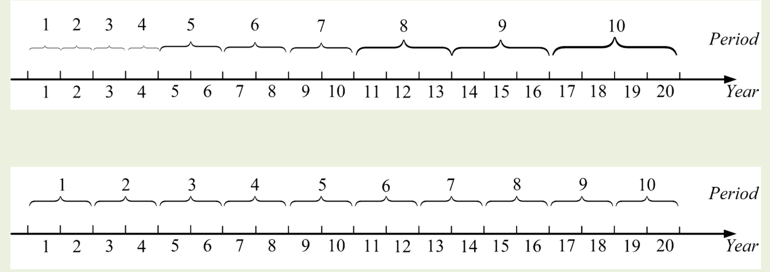
Scenario Generation

Moment matching method:



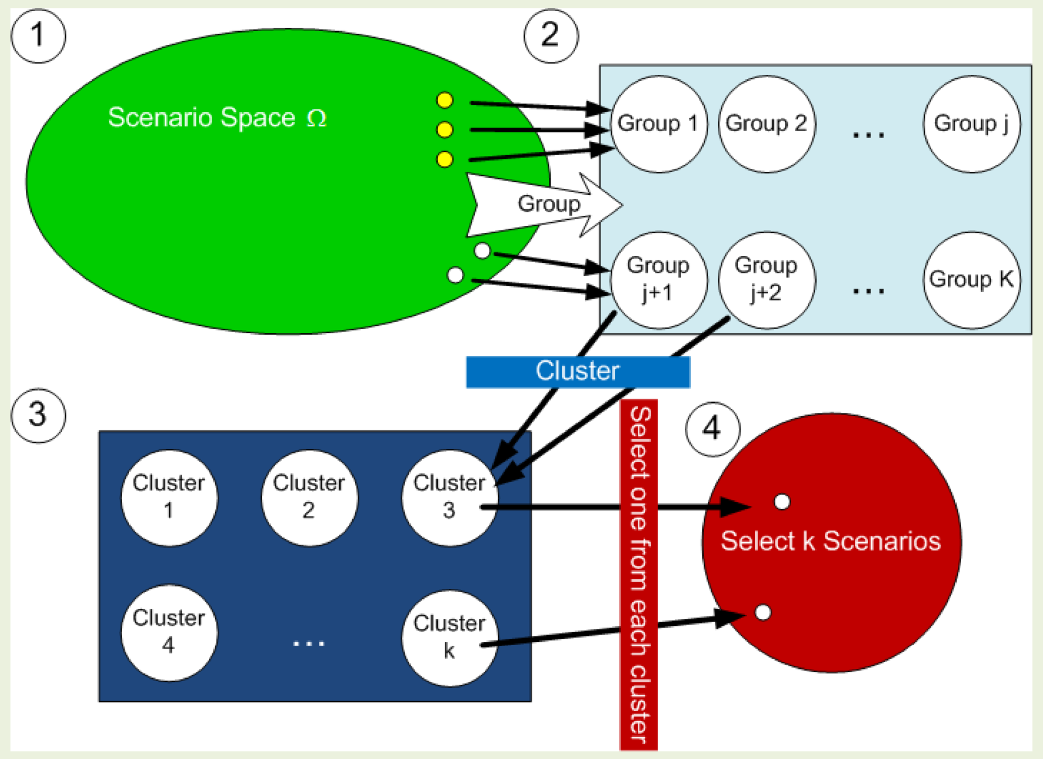
Control the size of scenario trees:

Divide 20 year horizon into 10 periods



Forward Selection in Wait-and-See Clusters (FSWC)

Select *k* scenarios from *N* original scenarios:



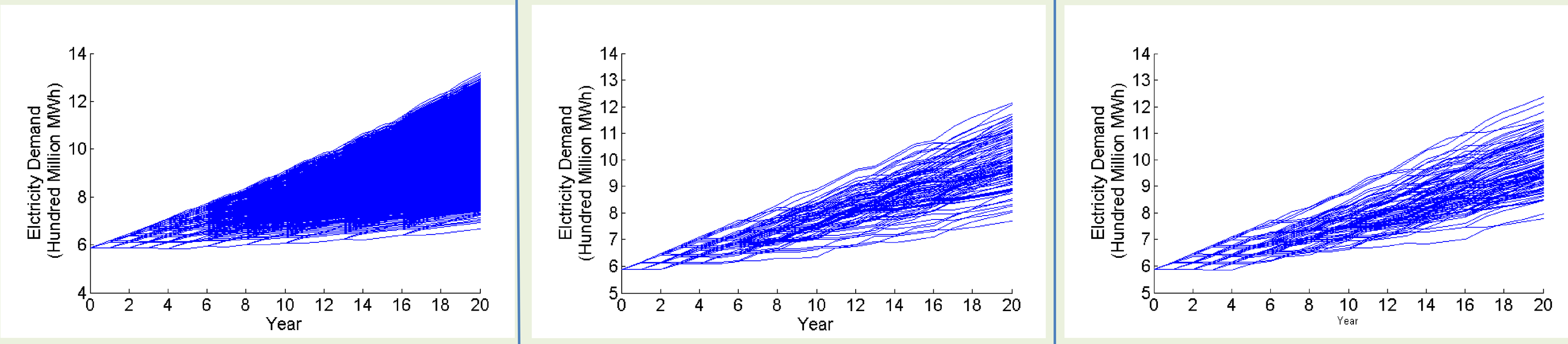
1. Solve deterministic problem for each scenario;
2. Form *K* groups of scenarios with same key first-stage decisions;
3. Create *k* clusters by *k*-means method;
4. Apply forward selection (FS) to select 1 scenario from each cluster

Case study

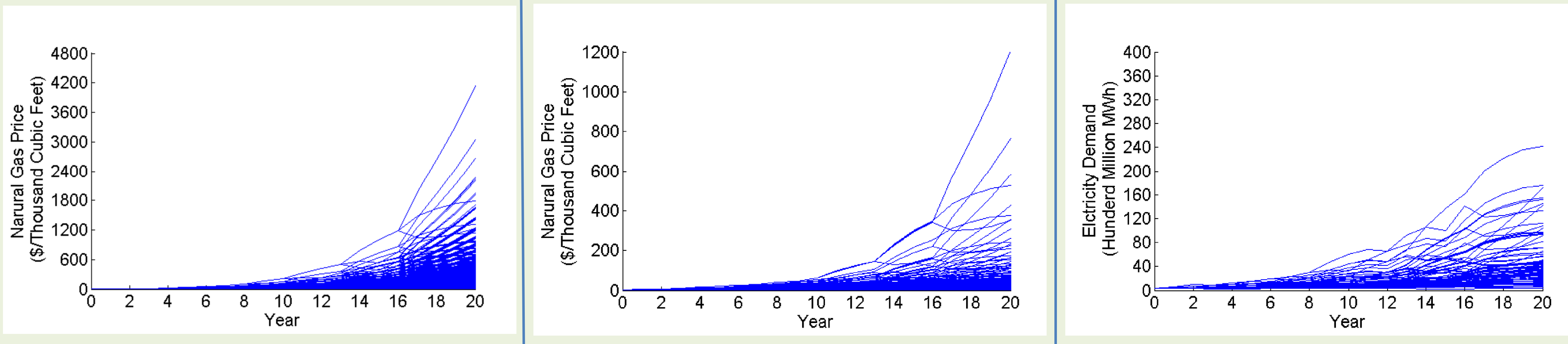
20 year generation expansion study, data from EIA

Original Scenarios: 3^{10} = 59049 Scenarios

Select 100 scenarios from original scenarios: FS (standard) Method: FSWC Method:

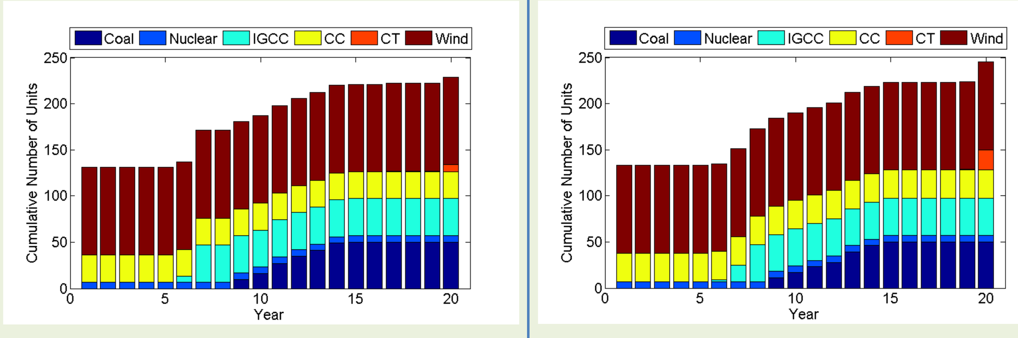


Demand vs. time — Demand vs. time — Demand vs. time



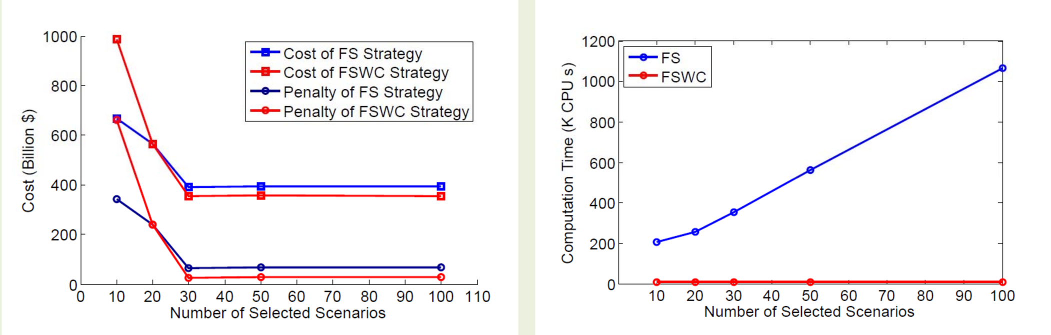
Price vs. time — Price vs. time — Price vs. time

Comparison of expansion strategies:



Number of units vs. time — Number of units vs. time

Expected costs evaluated against original scenario set:



Cost comparison — Time to select and solve

Potential uses of this research

- Planning under uncertainty
  - Long term: expansion planning
  - Short term: unit commitment
- Rolling horizons: solved repeatedly
- Scenario reduction emphasizes initial decisions