Using Deferrable Demand to Meet Renewable Portfolio Standards and Emission Reduction Targets (3.3)

Research Team

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Summary

Premises:

1) Need improved methods for evaluating the operations and planning of a future grid with:
    a. High penetrations of renewable sources,
    b. Storage and deferrable demand,*

2) Establishing public support for the future grid will require that customers see tangible benefits (e.g. lower bills).

* Decouples the purchase of electricity from the delivery of an energy service

Contributions:

1) Developed an *integrated multi-scale physical and economic* framework for modeling deferrable demand,

2) Evaluated the effects of *stochastic renewable sources* and *deferrable demand* on total system costs and emissions from generating units (to be completed).

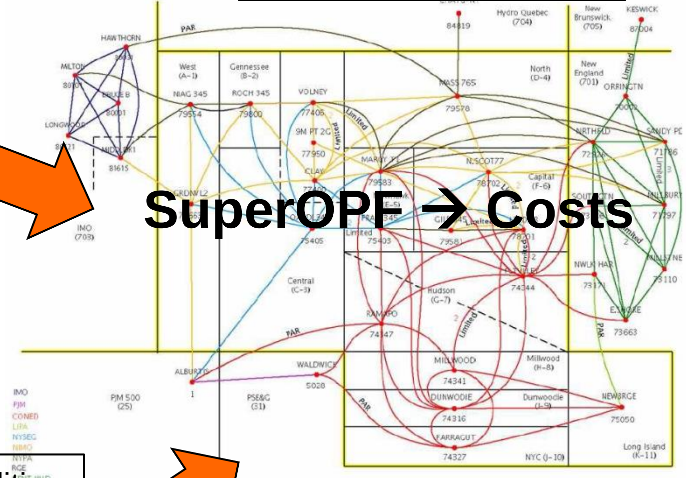
Accomplishments

1) Developed a model *for aggregating customers with electric vehicles* to determine the maximum hourly charge limited by the capacity of chargers and commuting patterns,
2) Developed a model for *aggregating buildings with thermal storage capabilities for cooling* limited by the capacities of compressors and the energy stored,
3) Used #1 and #2, in addition to *stochastic wind generation*, as inputs into the SuperOPF, a stochastic form of multi-period Security Constrained Optimal Power Flow (SCOPF),
4) Augmented the SuperOPF by adding *emission/damage coefficients* to the operating costs of generating units,
5) Used #1- 4 to simulate the *system effects and costs* of using deferrable demand to mitigate the variability of generation from wind sources and reduce emissions (to be completed).

Context of the Research:
An Integrated Multi-Scale Framework

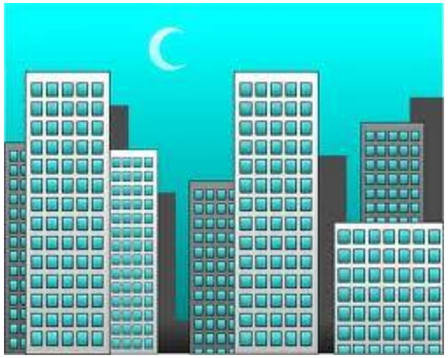
PEV charger capacities → Commuting Patterns → Nodal Capabilities

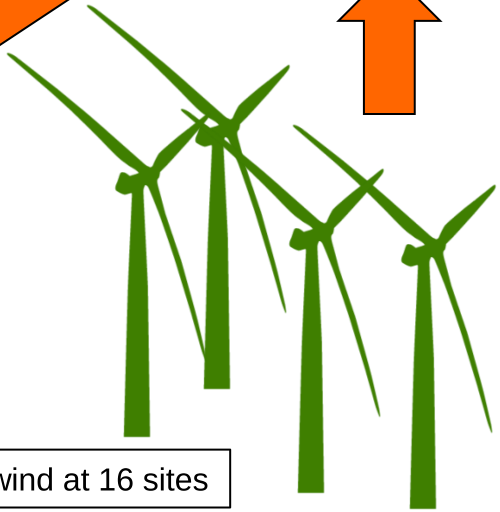
North East Test Network



SuperOPF → Costs

Ice storage systems → Buildings → Nodal Capabilities

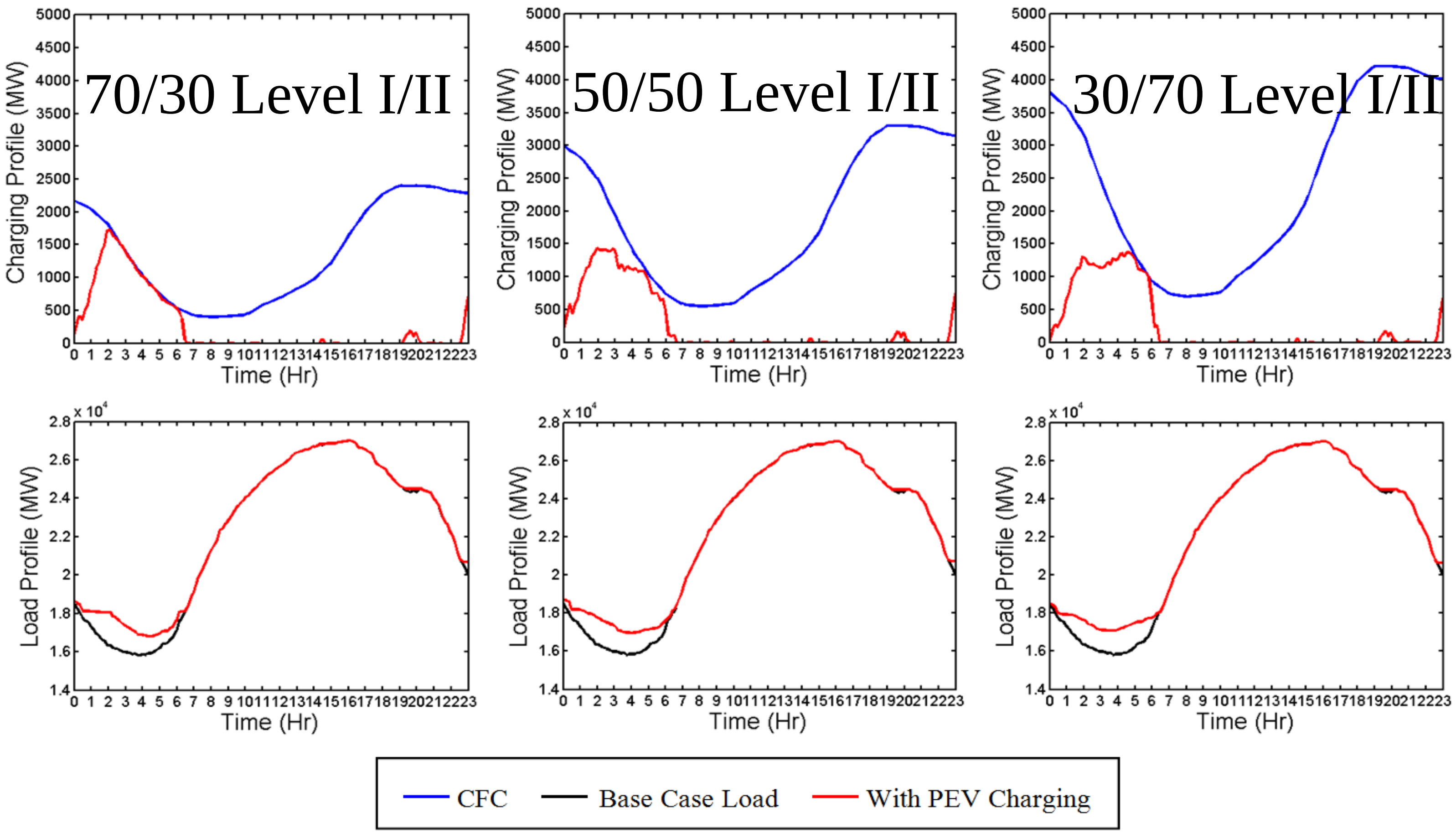




Stochastic wind at 16 sites

Results I:

System Load with “Intelligent” Charging of PEVs under Different Penetrations of Low and High PEV Charging Rates

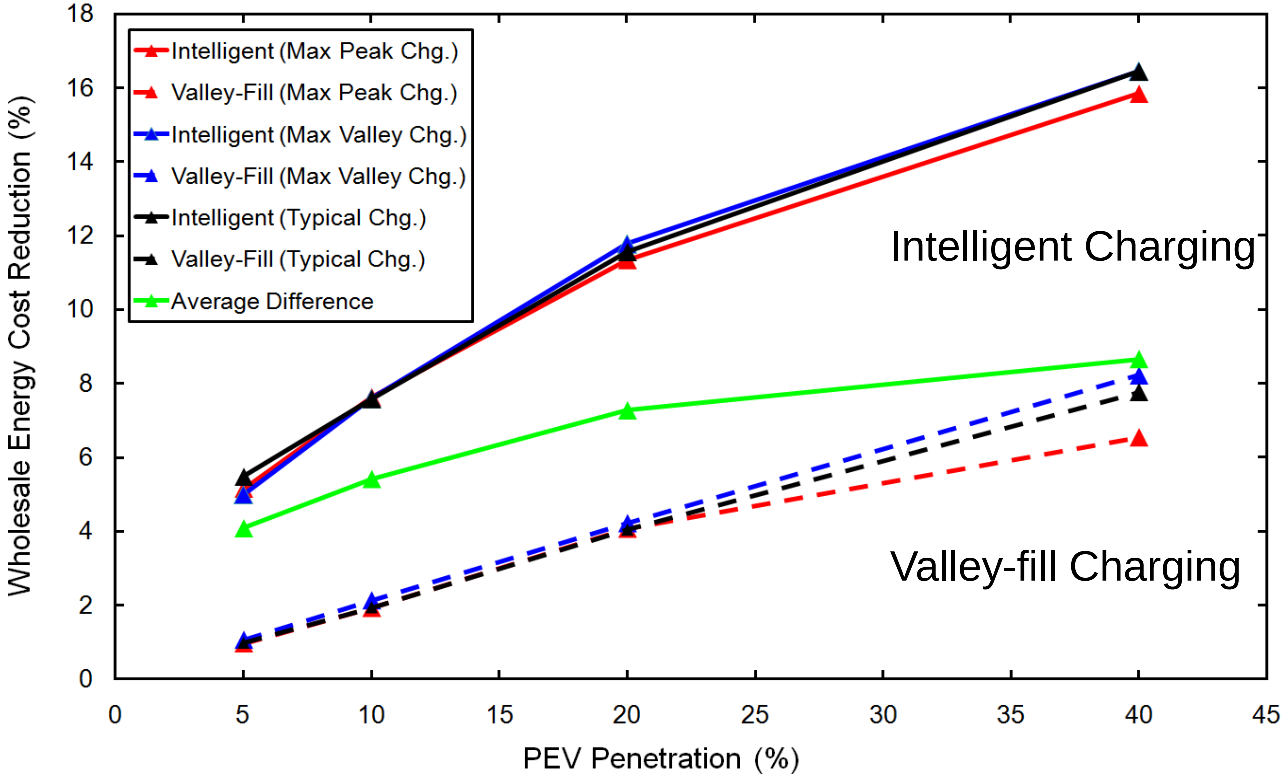


- A 20% penetration of commuters are assumed to use PEVs in the NPCC region
- 80% of the PEV load is assigned to valley hours to take advantage of the low prices
- The remaining 20% is assigned to shoulder and peak hours to reduce ramping costs
- The Charging Flexibility Constraint (CFC) may restrict PEV charging during the morning commuting hours

Valentine, Temple and Zhang (2011) J. Power Sources,

Results II:

Percent Reduction in Wholesale Energy Costs Using "Intelligent" Charging and Valley-Fill Charging vs. Charging-at-Will

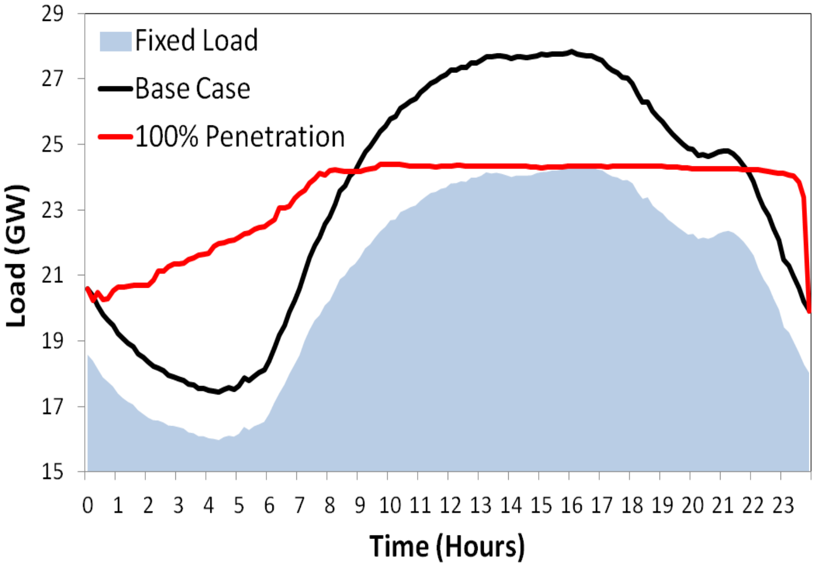


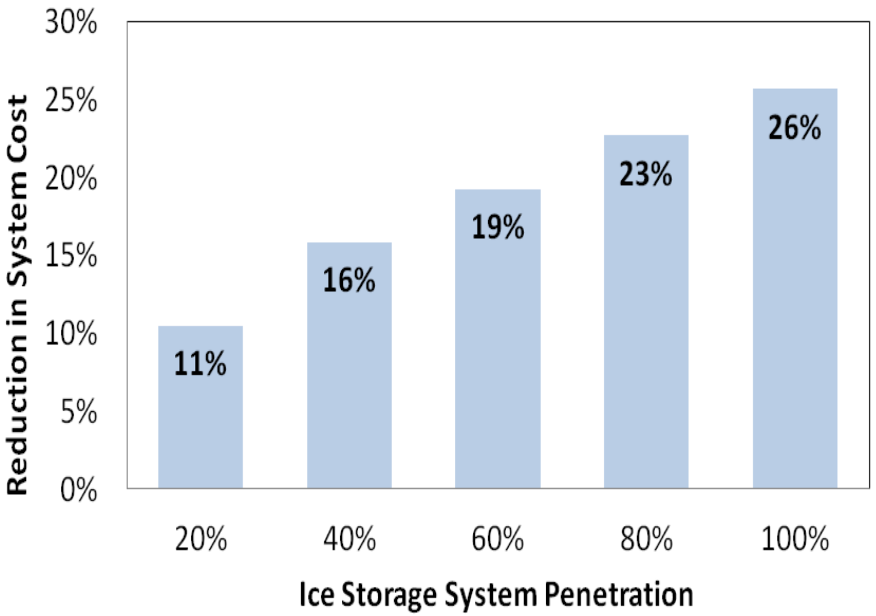
- Charging-at-Will (i.e., commuters charge their PEVs as soon as they arrive at home) is the baseline,
- Intelligent charging results in significant reductions in the costs compared to charging-at-will and valley-fill charging,
- Percentage reductions in the costs with intelligent charging are higher with higher penetrations of PEVs because more PEVs provide a greater capability for modifying wholesale prices and the system cost of ramping.

Valentine, Temple and Zhang (2011) J. Power Sources,

Results III:

System Load and System Cost Reductions with Price-Responsive Ice Storage Systems





- The system benefits of aggregating Ice Storage Systems in large commercial and industrial buildings in New York State were evaluated for the NYCA.
- Heuristic methods were used to reduce system costs in a two-settlement wholesale market that accounts for both the steady-state costs and ramping costs of generating units.
- The optimal management of thermal storage significantly reduces both the peak load and total system costs, and also flattens out the daily load profile of conventional generating units.

Palacio et al. In preparation, 7

Results IV:

Structure of the SuperOPF

OBJECTIVE FUNCTION FOR DAILY OPERATIONS:

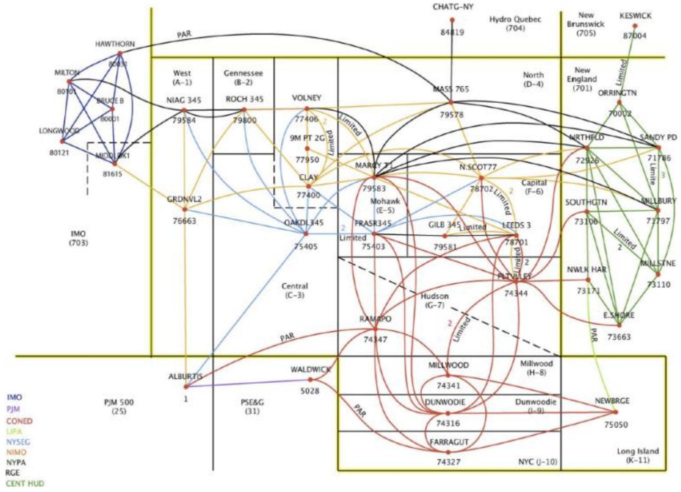
Minimize the expected cost of meeting load, including the costs of load-not-served, reserves and ramping, for a set of credible system states over 24 hours subject to:

1) Network constraints,
2) Stochastic wind inputs,
3) Contingencies.

DETERMINE THE OPTIMUM NODAL VALUES FOR:

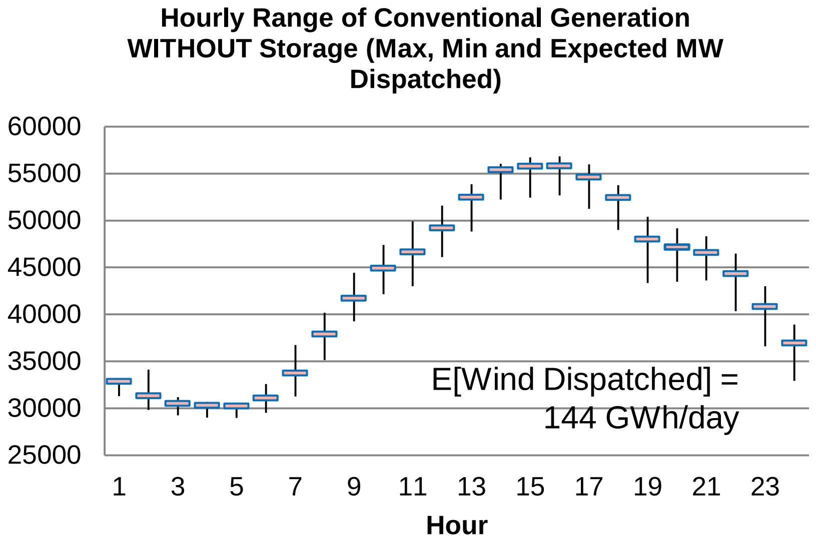
1) Hourly dispatch profiles for generating units,
2) Amount of wind dispatched/spilled,
3) Amount of Load-Not-Served,
4) Up and down reserve capacity,
5) Amount of ramping,
6) Nodal energy prices,
7) Charging/discharging of deferrable demand,
8) Charging/discharging of collocated storage,

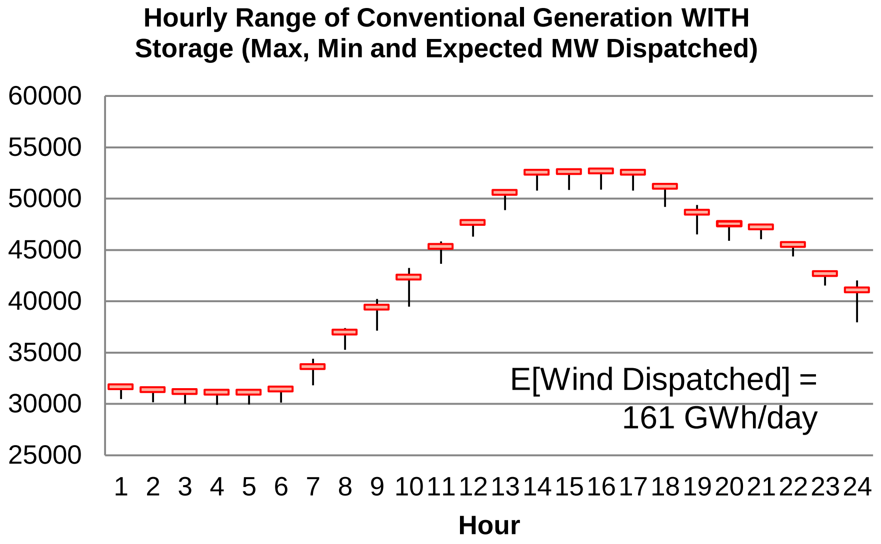
APPLIED TO:
North East Test Network (NET Net)
Hot Summer Day



Results V

The Effects of Storage (Deferrable Demand) on Ramping

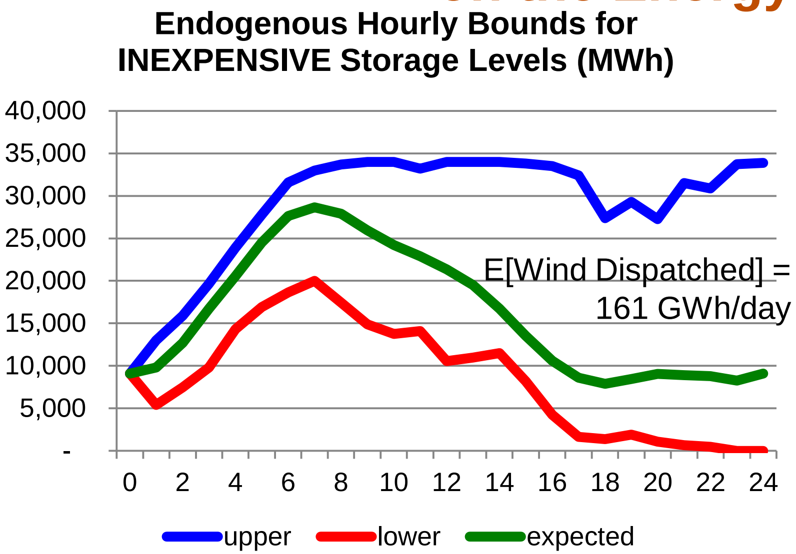


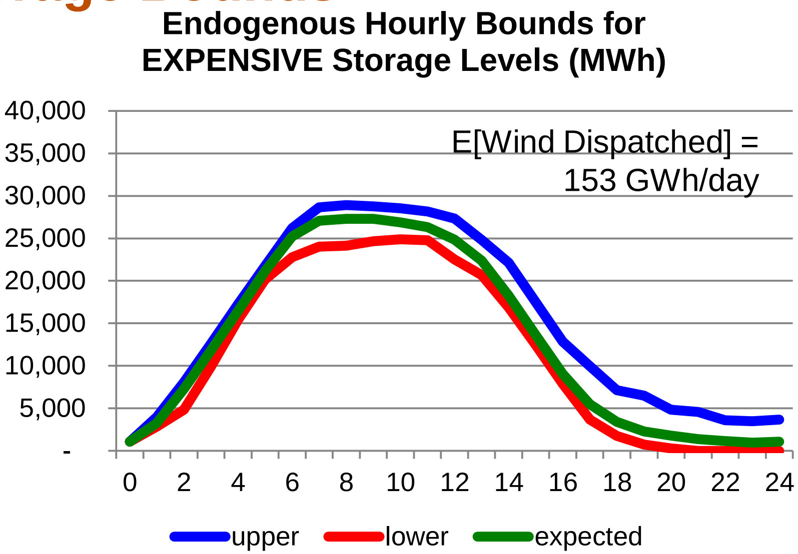


- ❑ The inherent uncertainty of wind generation for any hour requires some offsetting source of ramping services to offset it.
- ❑ With no storage capacity available, these ramping services are provided by purchasing reserve ramping capacity in advance from conventional generating units.
- ❑ If storage from deferrable demand is available to provide a relatively inexpensive source of ramping services:
  - ➢ More Wind Generation is dispatched,
  - ➢ Less ramping reserves are purchased from conventional generating units,
  - ➢ The peak dispatch of conventional generation is substantially lower,
  - ➢ The minimum dispatch of conventional generation is slightly higher.

Results VI

The Effects of the Cost of Ramping Provided by Deferrable Demand on the Energy Storage Bounds





- If deferrable demand can provide a relatively inexpensive source of ramping, then some of the storage capacity is reserved to mitigate the variability of wind generation.
- The expected amount of wind generation dispatched increases, and the range of possible levels of energy stored each hour also increases.
- If the cost of ramping provided by deferrable demand is relatively expensive (the same as the cost of conventional generating units) less capacity is used to mitigate the variability of wind generation, and:
  - Less wind generation is dispatched,
  - A higher proportion of ramping reserves is purchased from conventional generators,
  - The maximum amount of energy stored in any state of the system is lower,
  - The minimum amount of energy stored in any state of the system is the same,
  - The expected daily amount of up and down ramping from storage is higher.

Results VII

The Implications of Deferrable Demand for Regulators

- The availability of an inexpensive form of deferrable demand makes it feasible to:
  - Flatten the daily dispatch pattern of conventional generating units,
  - Mitigate the variability of wind generation,
  - Reduce ramping costs and maintain system reliability,
  - Lower the peak system load,
  - Lower system costs to customers.
- The economic viability of deferrable demand depends on restructuring retail rates for customers so that:
  - They pay real-time rates for energy to benefit from day/night price arbitrage,
  - They also pay demand charges proportional to their level of demand during peak load periods to provide an incentive to reduce their level of demand during peak load periods, and the cost of the installed generating capacity needed to maintain System Adequacy,
  - They can participate in ramping markets, by being metered separately, and get compensated directly for mitigating the variability of wind generation.

Environmental Analysis

(to be completed)

- Initially, fixed coefficients were used to link generator outputs and emission rates in the SuperOPF, but the emission coefficients for carbon are now being modified to depend on the generator types and operating conditions.
- Time-dependent and location-dependent damage coefficients are being developed to make it feasible to determine how dispatch patterns could be modified to reduce the severity of air pollution (e.g., ozone episodes).
- Using storage and/or deferrable demand may be effective ways to mitigate ozone episodes and increase social benefits by discharging more energy during critical periods when the damage coefficients of the precursor emissions are high (primarily NO_x).

Potential Benefits

1) Provide a comprehensive analytical framework for evaluating how deferrable demand (electric vehicles and buildings with thermal storage) can affect the operations and costs of an electric delivery system.
2) Demonstrate how deferrable demand can:
   - Flatten the daily dispatch pattern of conventional generators,
   - Mitigate the variability of wind generation,
   - Reduce ramping costs and maintain reliability,
   - Lower costs to customers,
   - Improve environmental quality (to be completed).
3) The software is open source, and when it is sufficiently robust, it will be added to the programs available with MATPOWER <http://www.pserc.cornell.edu/matpower/>.

Publications

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3. Mount, Tim, Judy Cardell, Lindsay Anderson and Ray Zimmerman, Coupling Wind Generation with Controllable Load and Storage: A Time-Series Application of the SuperOPF, Final Project Report for Project M-22*, PSERC Publication 12-29*, Nov. 2012.

4. Valentine, K.; W. Temple, and K. M. Zhang. Electric Vehicle Charging and Wind Power Integration: Coupled or Decoupled Electricity Market Resources? *Proceedings of the 2012 IEEE PES General Meeting*, San Diego, CA, July, 2012.

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11. Mount, Timothy D.; Alberto J. Lamadrid, Surin Maneevitjit, Robert Thomas, and Ray Zimmerman. The Hidden System Costs of Wind Generation in a Deregulated Electricity Market. *Journal of Energy Economics*, 33 (1), 173-198, 2011.

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