2008-2009 NPA-NREL Nebraska Statewide Wind Integration Study

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EnerNex CORPORATION

Renewable Energy Consulting Services, Inc.

Outline

- Study Background, Issues, Methods
- NPA 2018 System Description
- Scenarios Studied, Wind and Load Data
- Key Results
- Personal Perspective on Integration Costs

Background

- DOE-NREL contract with NPA
  - 2008 through 2009
  - Study initiated October 2008
- Subcontracts to power-system consultants
  - Enernex Corporation
  - Ventyx LLC. (now an ABB company)
- Oversight by Technical Review Committee
  - Nebraska utility staff members (11)
  - Technical experts and stakeholders (14+)
  - Observers (31+)

Key Issues

- Wind impacts on power system operations
  - Penetration levels: 10%, 20%, 40% of energy
  - NPA alone and NPA within SPP
- Wind integration costs
  - Reserves requirements (statistical analysis)
  - Hourly operation impacts (dispatch)
  - Day-ahead planning impacts (commitment)
- Wind energy utilization
  - Degree of curtailment

Study Methods

- Use standard utility-system planning tools
  - Hourly production costs for entire years
  - Statistical analysis of reserve generation based on industry experience
- Examine scenarios with and without wind
  - Serve entire customer demand in all cases
- Requires a “proxy resource” for the no-wind cases
  - Equivalent energy content
  - Without wind’s variability and uncertainty
  - Easier said than done

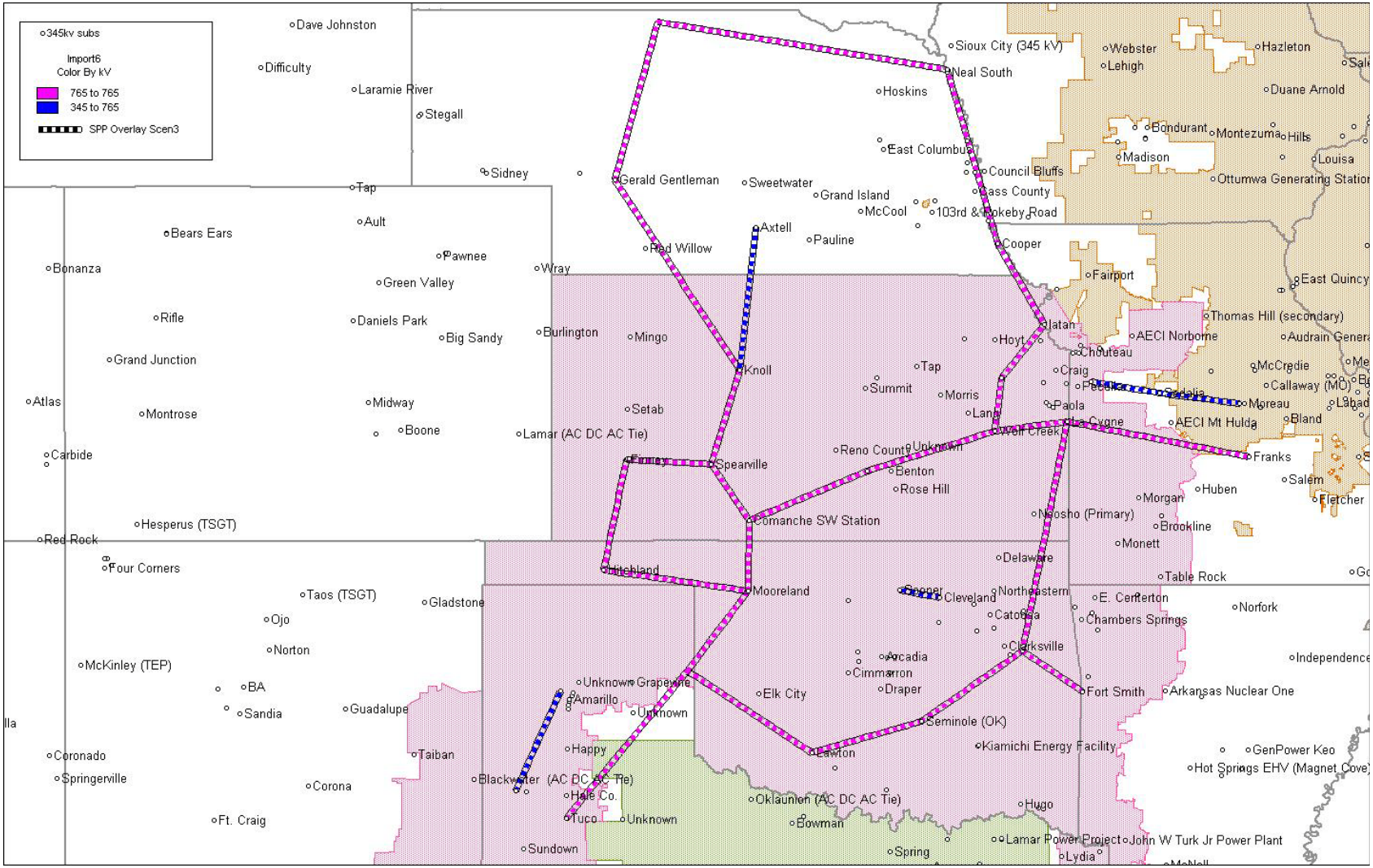
Study Methods

- Simulated operation of NPA system for 3 years
  - NPA alone (as a single, combined balancing area)
  - NPA within SPP (unified market)
- Simulation ensures sufficient generation to meet demand at all times; includes reserves to cover contingencies, as well as variability and uncertainty in wind and load
  - Increasing reserves as wind penetration grows is reflected in commitment (day-ahead) and dispatch (hourly) decisions

2018 Nebraska System

- 2008 system with known additions to generation capacity and transmission
  - Peak load scaled up to 2018 projection
  - Load shape maintained – daily and seasonal
- Wind data from NREL meso-scale data sets
  - 2004, 2005, 2006; 10 minute data
  - Developed by AWS Truepower from NWS historical weather data
  - Correlated NPA load data used for same years
- NPA integrated into the SPP system
  - Results obtained for NPA alone and NPA in SPP

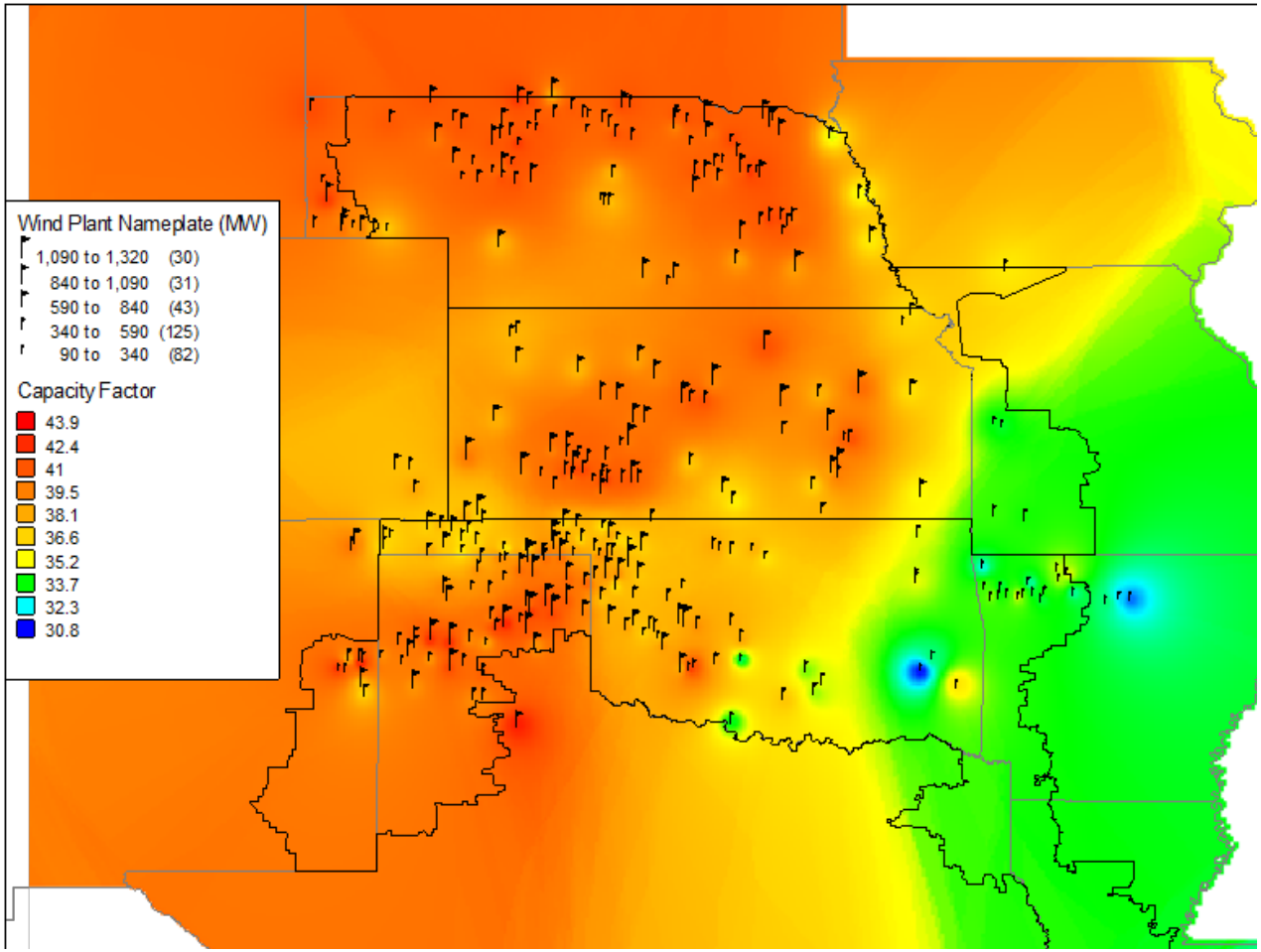
SPP EHV Overlay (with Nebraska loop)



Study Scenarios

- Four base case scenarios
  - 10% NPA wind, 10% SPP wind, no SPP EHV Overlay
  - 20% NPA wind, 20% SPP wind, no SPP EHV Overlay
  - 20% NPA wind, 20% SPP wind, with SPP EHV Overlay
  - 40% NPA wind, 40% SPP wind, with SPP EHV Overlay
- Installed wind capacities:
  - NPA: 1.2 GW, 2.5 GW, 4.7 GW
  - Rest of SPP: 6.3 GW, 12.6 GW, 25.4 GW
  - Most of remainder of Eastern Interconnection: 50 GW (about 6%)

NREL Meso-scale Wind Data

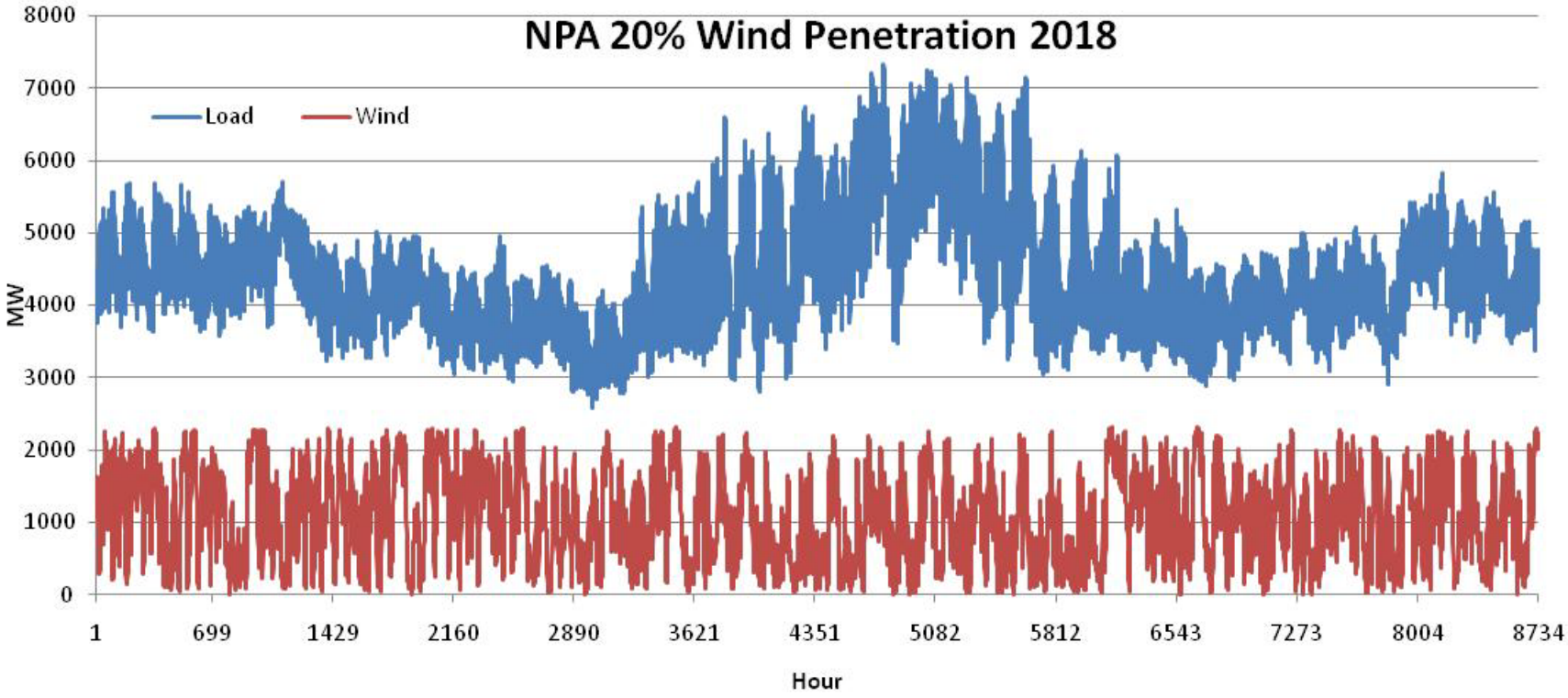


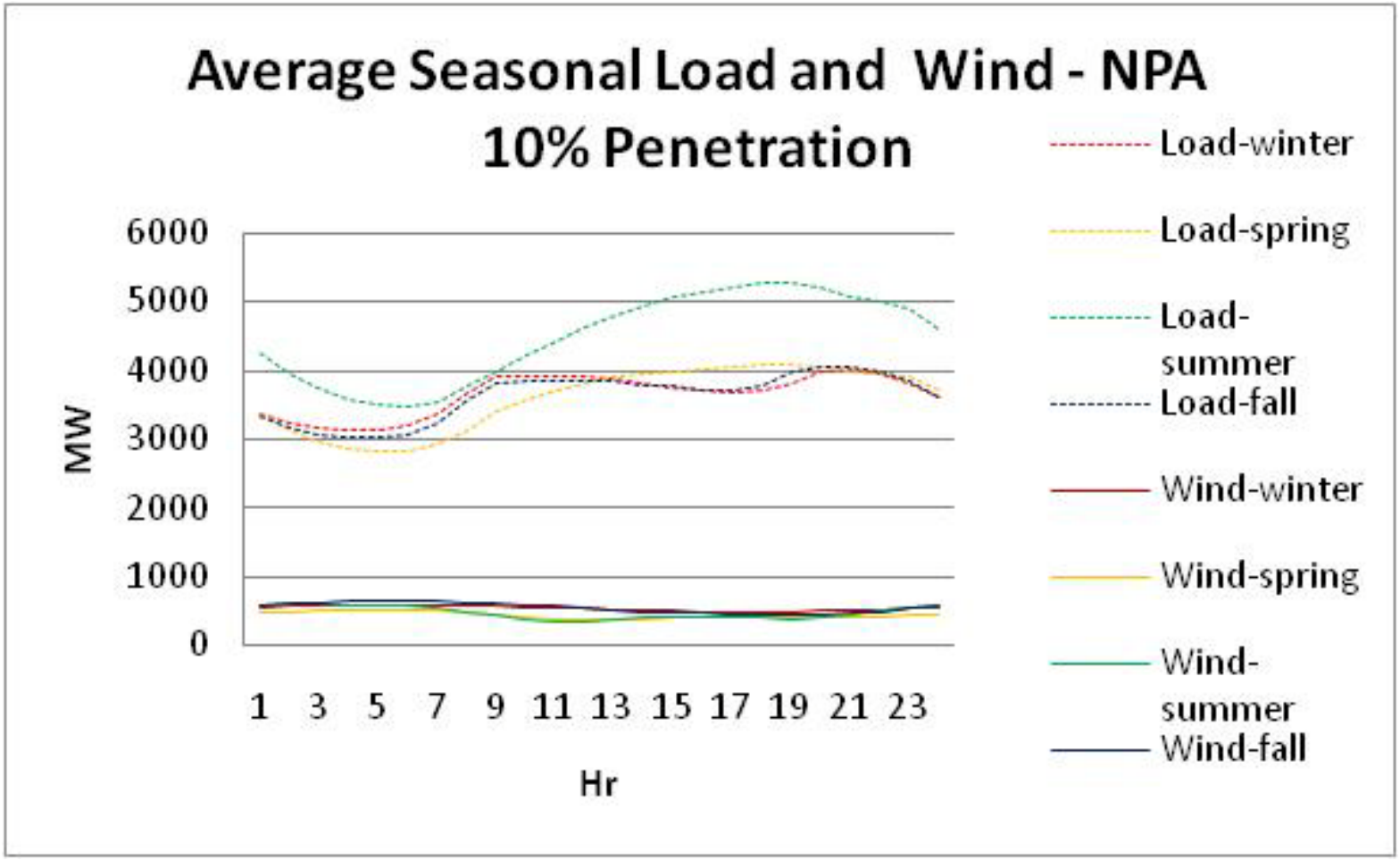
NREL data, developed by AWS Truepower. Wind generation data for 80-meter heights: **"Actual" at 10-minute** intervals and hourly. **"Forecasts" of hourly** with lead times of day-ahead, 6 hours and 4 hours (only day-ahead used in NPA study). **Years involved:** 2004-2006. **Spatial resolution:** 2 kilometers between "sample" points.

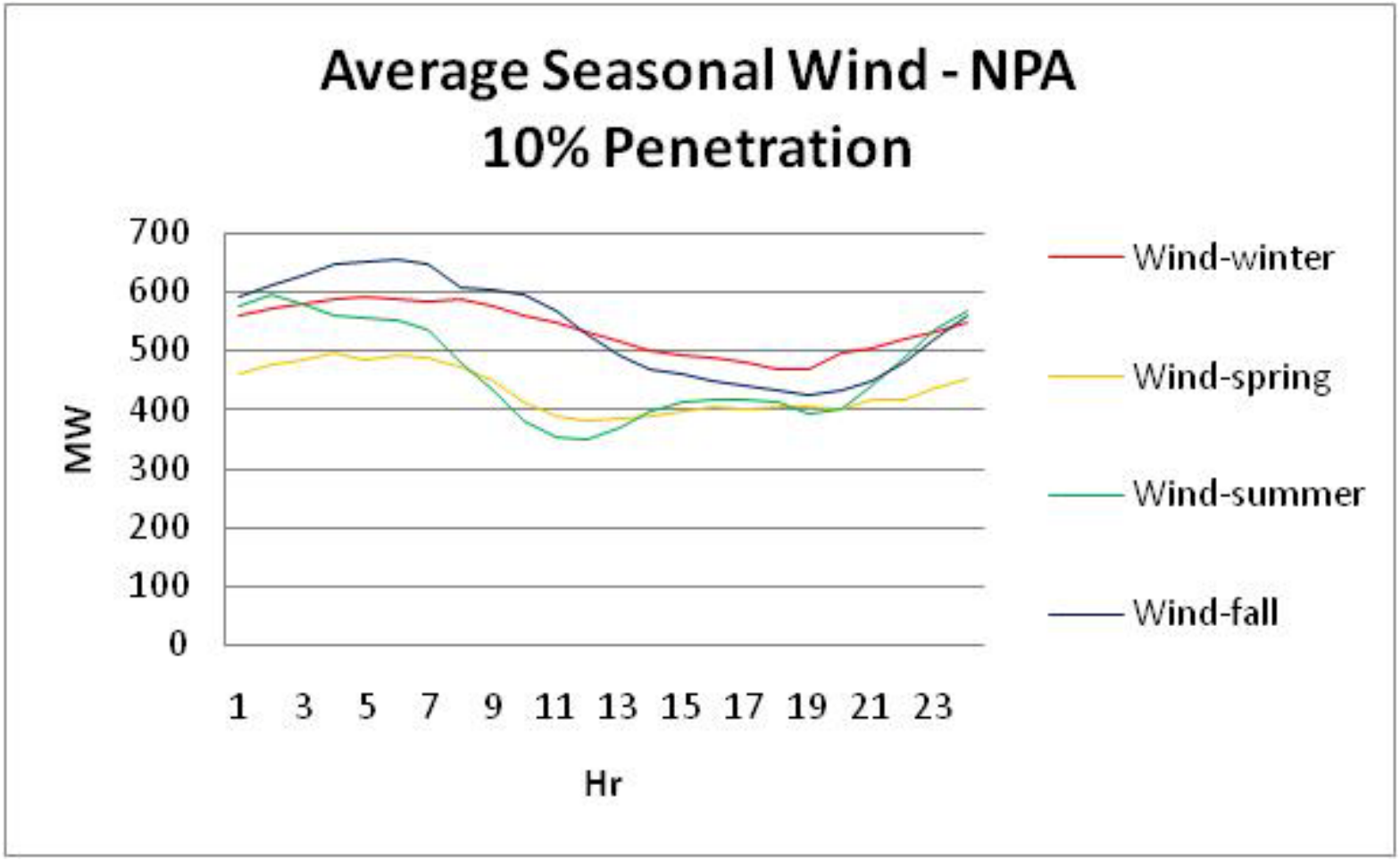
Wind Generation Characteristics (40% case)

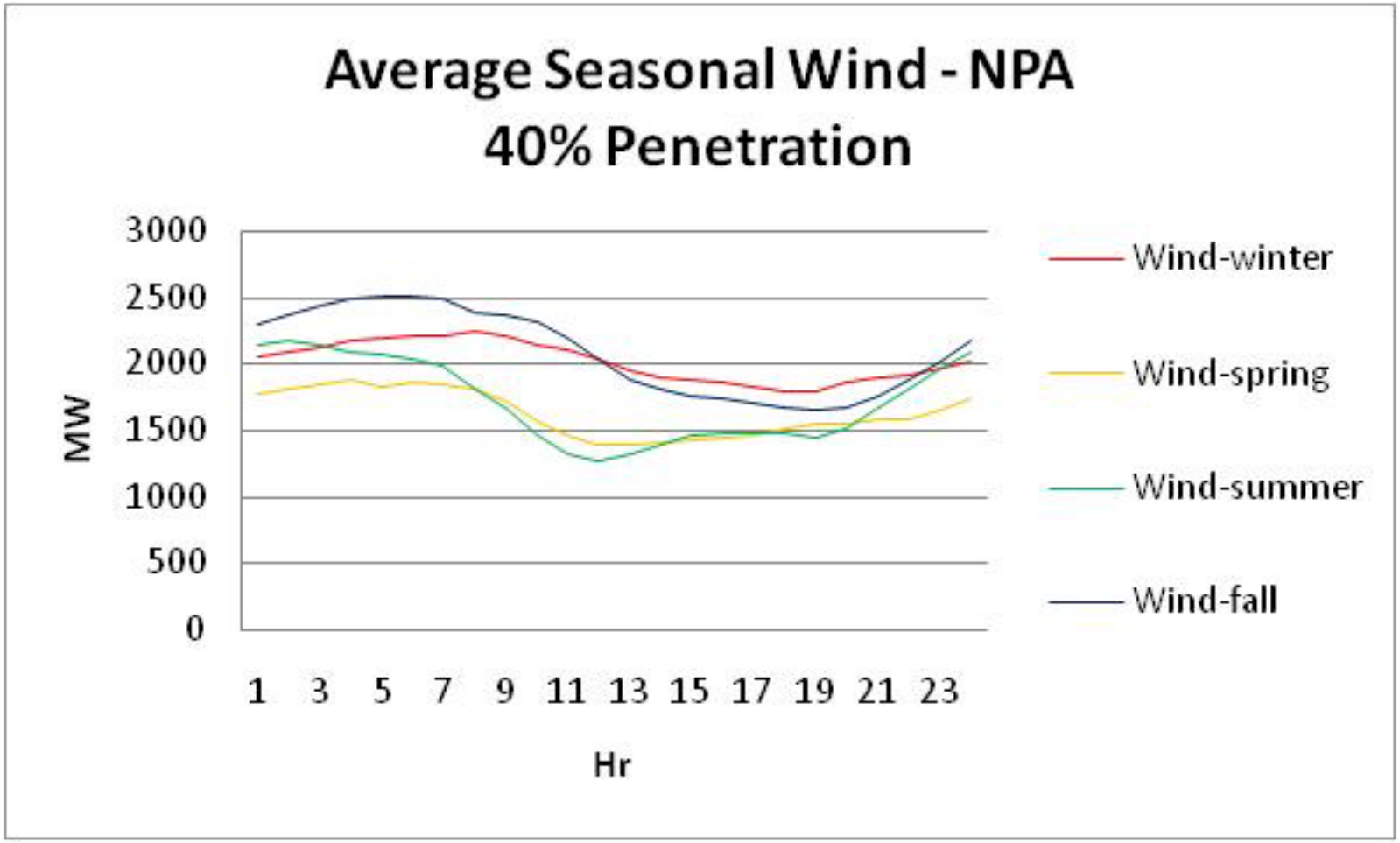
- Aggregate capacity factor for all sites chosen from the NREL data base
  - 2004: 39.5%
  - 2005: 41.0%
  - 2006: 42.9%
- Day-ahead forecast mean absolute error for the Nebraska portion of the NREL data:
  - 10.83%

Wind and Load Data Drive Analysis




Average Seasonal Load and Wind - NPA
10% Penetration
6000
5000
4000
3000
2000
1000
0
MW
1 3 5 7 9 11 13 15 17 19 21 23
Hr
Load-winter
Load-spring
Load-summer
Load-fall
Wind-winter
Wind-spring
Wind-summer
Wind-fall

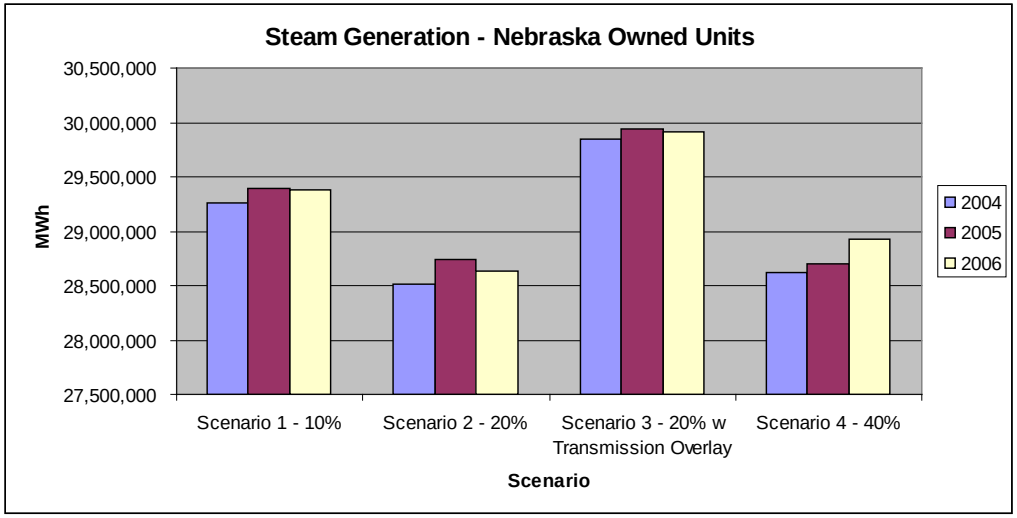

Average Seasonal Wind - NPA
10% Penetration
700
600
500
400
300
200
100
0
MW
1
3
5
7
9
11
13
15
17
19
21
23
Hr
Wind-winter
Wind-spring
Wind-summer
Wind-fall

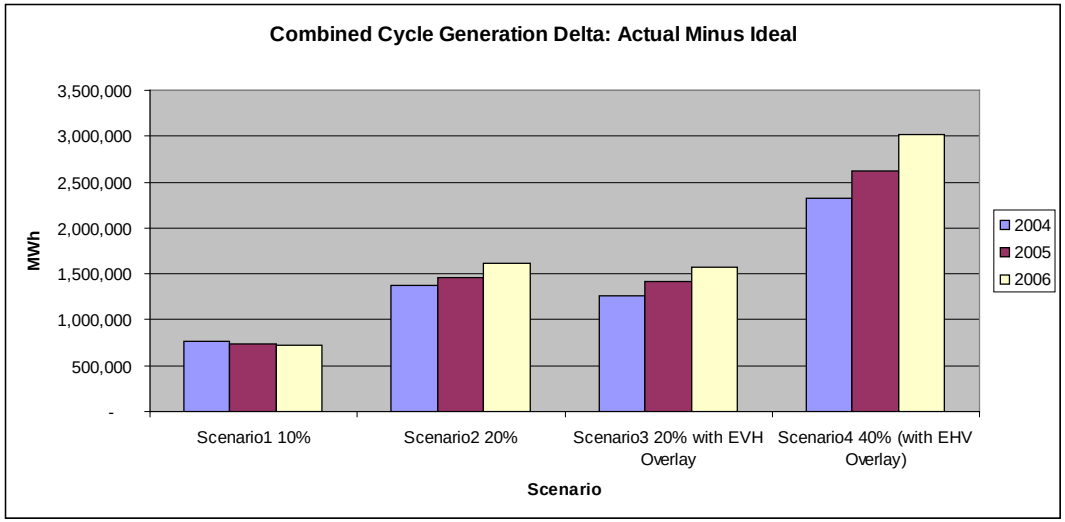

Average Seasonal Wind - NPA
40% Penetration
3000
2500
2000
1500
1000
500
0
MW
1
3
5
7
9
11
13
15
17
19
21
23
Hr
Wind-winter
Wind-spring
Wind-summer
Wind-fall

Study Results: Wind Energy Usage

- Wind Energy Curtailment: No significant curtailment in Nebraska in any case with or without the overlay
- In the rest of SPP for the base cases, curtailment was found to be:
  - 2% at 10% penetration without the overlay
  - 7% at 20% penetration without the overlay
  - 0% at 20% penetration with the overlay
  - 5% at 40% penetration with the overlay
- Wind Energy Usage: As wind penetration increased, wind exports from SPP (including Nebraska) increased by half the amount of the wind generation increases.

Steam Generation Varies with Wind and Transmission





Combined Cycle Generation increases with variability and reserves

SPP Regulating Reserves (2006 pattern, hourly maximums)

Wind Penetration		Load Only(MW)	Wind & Load (MW)	Increment (MW)
10%	(7.5 GW)	528	1152	852
20%	(15.1 GW)	528	1800	1542
40%	(30.2 GW)	528	2357	3034

- Incremental reserves roughly proportional to wind penetration
- Provided by existing generating units

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*Incremental reserves for NPA separately and Rest of SPP separately would be 177 MW and 821 MW, respectively, totaling to 998 MW

Combined operation reduces reserves by 146 MW

Study Results: Integration Costs

- Difference between yearly production costs with and without wind
  - Expressed per MWh of wind energy
- Depends on characteristics of the proxy resource
  - Provides same amount of energy as the wind
  - Relatively benign shape
  - Daily flat block? Hourly flat block? Shaped like the wind forecast? Rolling averages?

Study Results: Integration Costs (2009$)

- 10% to 40% Wind, Shaped Proxy, three years,
  - Integration costs ranged from $1.39 to $1.68/MWh
  - Well under 10% of wholesale value
  - Consistent with many other integration studies
- Several different proxies examined for 10% and 20% Wind
  - At 20%, costs ranged from $1.45 to $4.29/MWh
  - Still under 10% of wholesale value
- Some wind energy exported from SPP, so some integration costs may also be exported
  - At 10%, total cost could be as high as $5.41/MWh
  - Very preliminary – likely an upper bound

Study Results: Other Key Findings

- Transmission: will be stressed with high wind penetrations; expand with wind in mind
- The 765 kV overlay will certainly reduce stress and congestion
  - Perhaps even at lower voltage
  - But caution needed on undersizing
  - Much more study needed
- CO_2 emissions: reduced as wind penetration increases – about 10 million tons/yr for each 10% of wind penetration for all of SPP

A Note of Caution On Integration Impacts

- There may be some additional costs associated with managing wind generation not captured in these production simulations:
  - Additional maintenance and forced outages and generating-unit deratings
  - Degradation of heat rate from ramping, cycling and range of operation
  - Increase in emission rate per MWh production
- Further study is needed

Integration Costs: Personal Perspective

- Over a dozen integration studies since 2001
  - Early concern: Would integration costs exceed the value of the wind energy?
  - Concern laid to rest with the first study (2002)
  - Integration cost under 10% of wholesale value
  - Corroborated by all subsequent peer-reviewed integration studies up to ~ 30% wind energy
- Two main reasons:
  - Sharing reliability responsibilities over larger regions reduces operating costs (e.g., reduced reserve-capacity needs)
  - Aggregating wind over larger regions mitigates wind variability (e.g., some averaging occurs)

Integration Costs: Personal Perspective

- Key question about integration costs has been answered: Will integration impacts and costs seriously degrade wind's value? NO
- Should we continue to calculate these costs?
  - Pro: they provide useful information that helps system operators better understand their costs
  - Con: the results can only be approximate
  - Con: we don't do this for other generation types (e.g., baseload nuke not easily controlled on short notice)

Integration Costs: Personal Perspective

- One prominent utility consultant group (GE) has conducted several of the major integration studies
  - They have never calculated integration costs!
  - They examine wind's total aggregate impacts – benefits and costs rolled together
- An overriding lesson from all of the studies: *sources of flexibility will reduce operating costs in general, and will aid in integrating wind*; e.g.,
  - Shorter term markets; shorter dispatch intervals
  - More flexible generation; demand response
  - Increased connectivity (transmission expansion)
  - Economical storage; wind curtailment
- Many of these changes are coming irrespective of wind expansion

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