National Renewable Energy Laboratory
Innovation for Our Energy Future

Wind Power Integration Studies

Energy Modeling Forum

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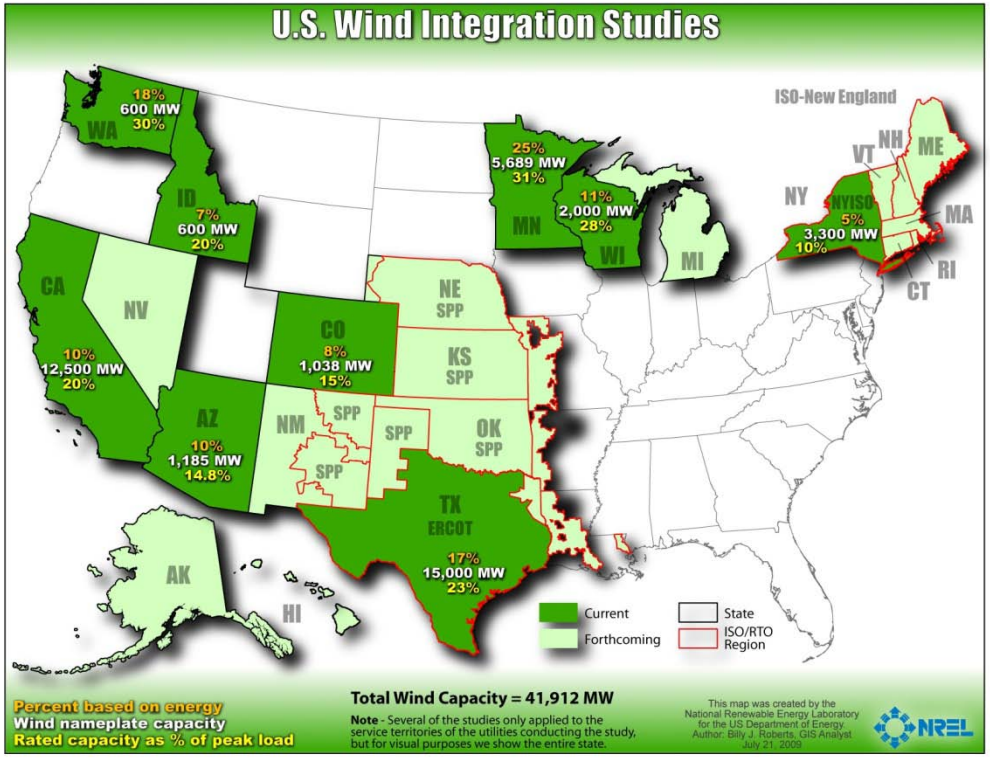
Wind Power Integration Studies

- Wind Power is a new and growing energy resource
- Utilities, ISOs/RTOs, regulators, and researchers are trying to understand impacts that higher penetrations of wind will bring
- These entities will often initiate wind power integration studies that attempt to simulate the power system with high amounts of wind
- The objective is to learn operating impacts and cost impacts
- Different studies cover different objectives and impacts vary, but general conclusions are usually similar

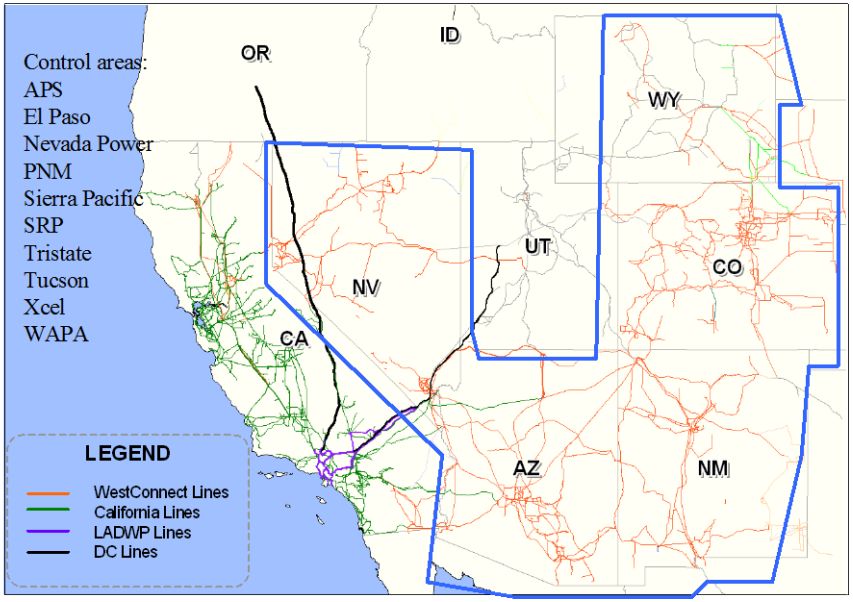
Wind Power Integration Studies

- Results of the studies are used in many different ways
  - NYISO studied 3300 MW which later became a limit in its tariff
  - Some studies use results of integration costs as a basis for interconnection of new wind
  - Most help planners and operators in preparing for potential new rules and procedures



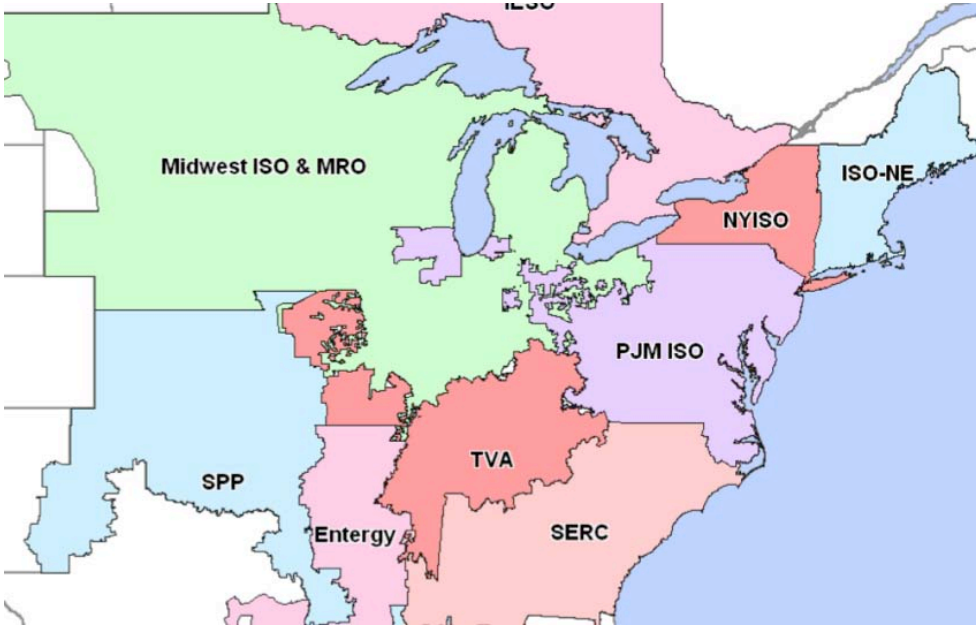
Current NREL studies

Western Wind and Solar Integration Study (WWSIS)



Different scenarios of 30% wind/5% solar in Westconnect Utilities

Eastern Wind Integration and Transmission Study (EWITS)



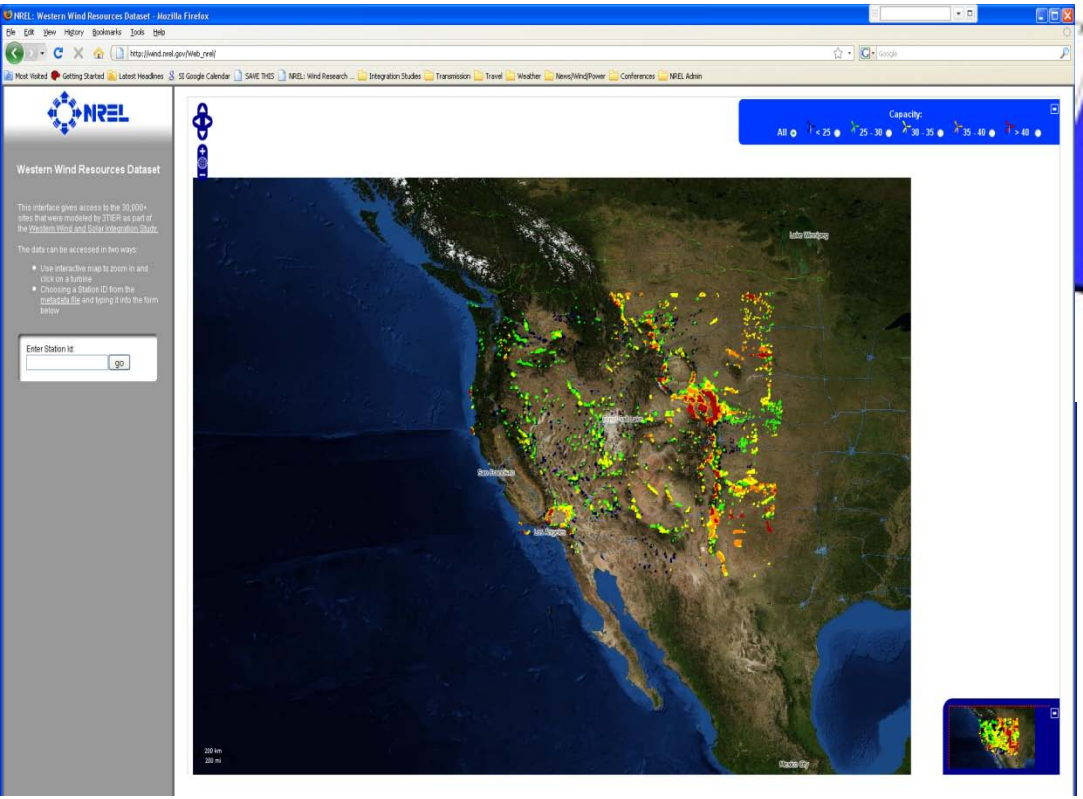
3 scenarios of 20% wind and 1 scenario of 30% wind

Integration Study Stages

- Data Gathering: Renewable energy, demand, network, other generation
- Data Validation: Is the modeled data accurate?
- Scenario Development: Specific objectives and assumptions
- Reliability Assessment: Capacity value of renewable, voltage and stability analysis
- Operational Analysis: Integration costs, transmission flows, generation commitments, emissions
- Characteristics and Statistical Analysis: reserve requirements, geographic diversity impacts, ramping behavior
- Results and conclusions

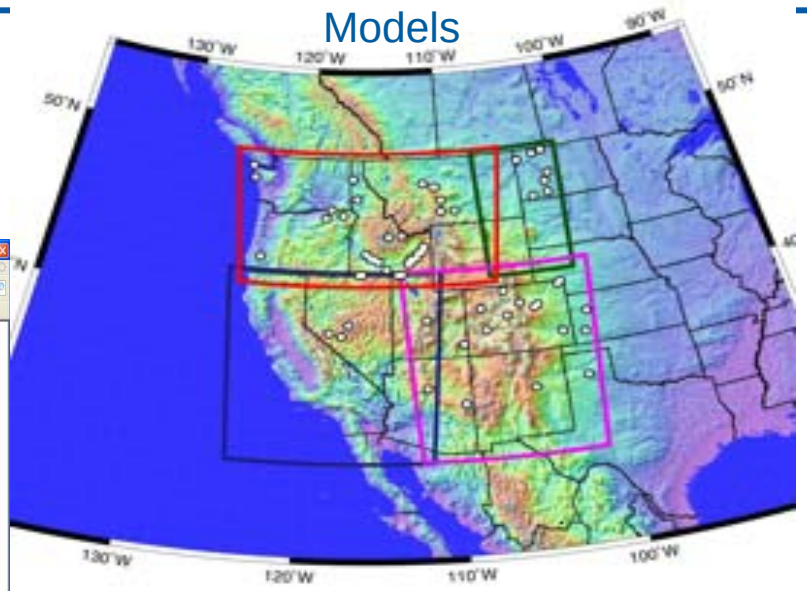
Data Gathering

- ✓ Large realistic datasets representing future wind sites



- ✓ Demand, transmission, and generation data obtained from participating utilities

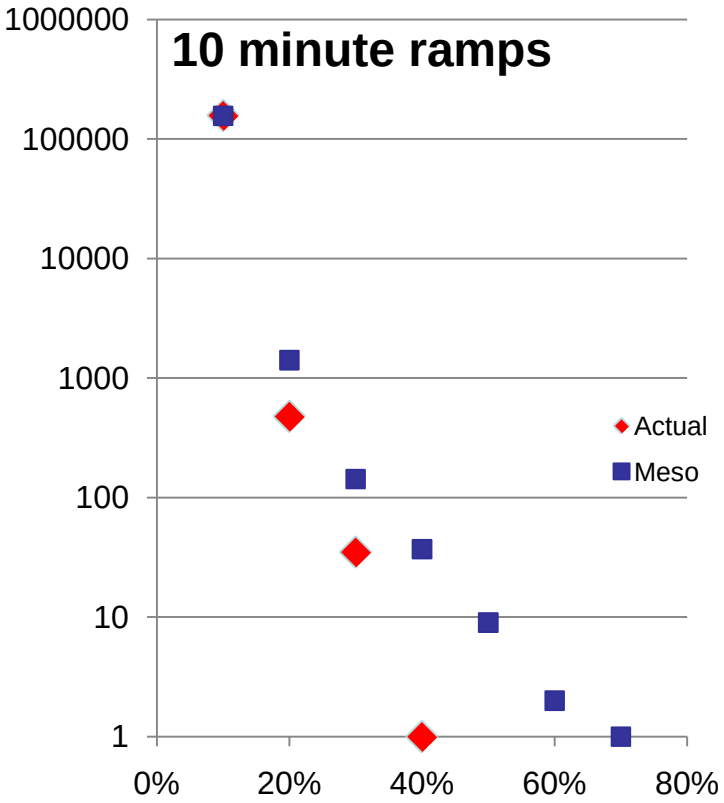
Numerical Weather Prediction Models



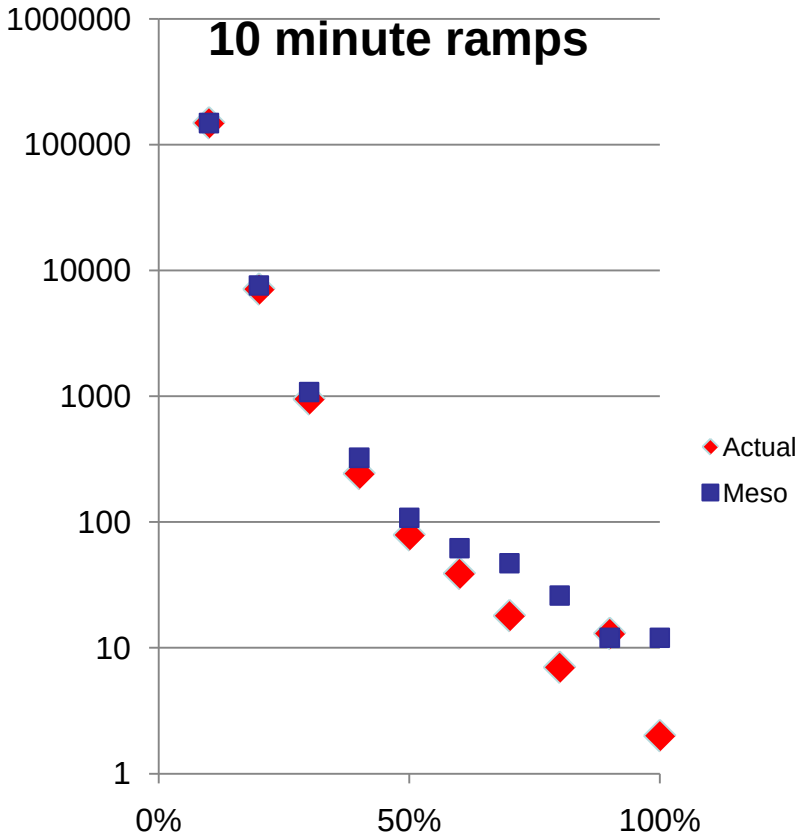
- ✓ Weather years for wind should match load
- ✓ Areas for wind chosen based on capacity factor, load correlation, and transmission proximity
  - ✓ Parks, urban areas, other restricted areas excluded
- ✓ WWSIS – 2 km resolution, 10 min time series, 3 years, 900 GW of wind sites; i.e., lots of data

Data Validation

Data Validation of this huge dataset is crucial. Wind ramps were most important – Had to ensure they were realistic



536 MW in Texas



Other state

Scenario Development

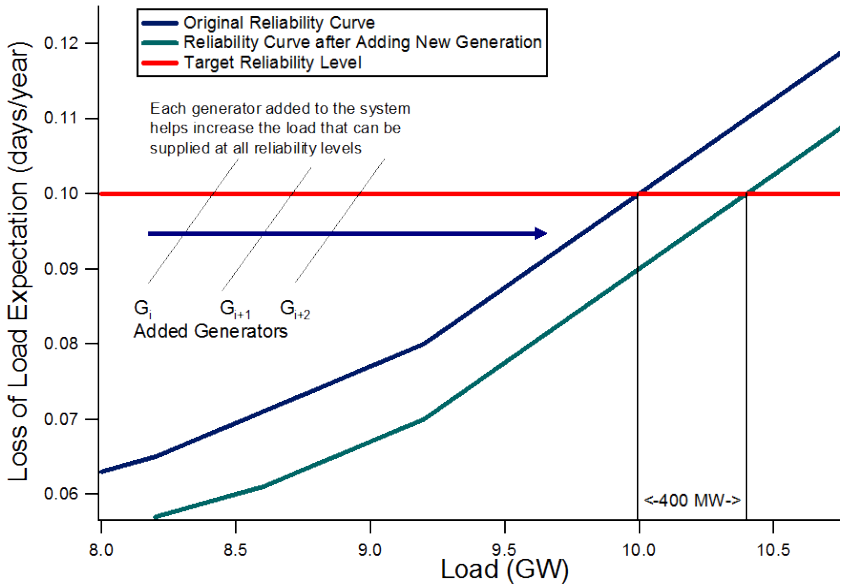
- What are the objectives?
- What scenarios best meet these objectives?
  - What additional transmission will be built?
  - What additional conventional generation will be built?
  - What other types of resources should be integrated into study? (e.g., storage, demand response)
- How much wind/renewables?
- Where should the wind/renewables be located?
- EWITS Scenarios
  1. 20% lowest cost wind high transmission scenario
  2. 20% hybrid scenario
  3. 20% Load-weighted aggressive offshore scenario
  4. 30% combinations of 1 and 3

Study Analysis

- With this data, many sophisticated techniques will be used to evaluate the power system with high penetrations of wind at different time frames
- Planning – Analysis goes into the evaluation of reliability that additional wind brings to the system and estimates on its ELCC
- Operations planning – Simulations are run to see the impacts of wind on unit commitment and dispatch as well as any changes in costs
- Characteristics of wind – Statistical approaches are used to give operators and planners a feel for how the wind will behave and can use the variability statistics in methods of calculating operating reserve.

Reliability Assessment

- Using LOLP or related metric, what is the ELCC of the added wind
- Time Synchronized wind and load data becomes very important



Study	Penetration	Capacity Value
NY 2005	10% capacity	10% Onshore/ 40% offshore
MN 2006	25% energy	Depending on data year 4% to 17%
CO 2007[12]	15% capacity	12.5%

- Different years can have completely different values
- Many areas will use this data for capacity credit assignments when there is a lack of real data (i.e., when wind is first interconnecting)

Operations Analysis

- Two different questions: What are the cost savings of having more wind and what are the costs associated with the integration of all this wind
- Market simulations will run a SCUC model for all hours of a full year
- The simulation will model a day-ahead market committing units to forecasted wind and load values and then using these commitments and dispatching toward actual values
- Comparing total production costs with and without wind and using different methods can give integration costs or savings
- Show how perfect forecasts change the system

Study	Penetration	Integration Cost
2004 MN/XCEL	15% capacity	$4.60/MWh
2006 MN	25% energy	$4.41/MWh
2006 CO/XCEL	15% capacity	$4.97/MWh
2007 CA	20% capacity	$0.69/MWh

Typical Operational Simulation

For every day of the year

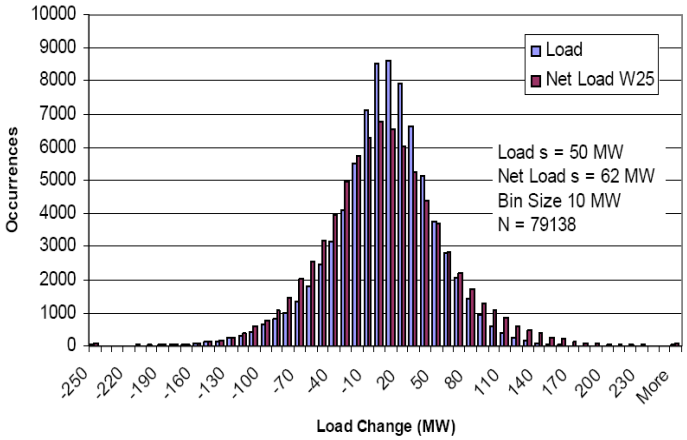
Minimize Variable Production Costs + Start-up costs + CO2 Costs + O&M Costs + Load Reduction Costs + …

Subject to

- Load balance
- Generation min/max capacity limits
- wind forecasts and wind production
- Network constraints (DC load flow)
- Security constraints (contingencies)
- Operating reserve requirements
- Generator commitment constraints (start, min run, etc.)
- Generator Ramp Rates
- …

Wind Characteristics and Statistical Analysis

- Most market simulations are on hourly resolution but intra-hour affects are important
- Statistical methods can show wind variability from one wind plant and how geographic diversity can reduce the per unit variability of multiple wind plants
- Variability metrics can be used to assess future reserve requirements
  - For ex. 3σ minute to minute variability often used as determination of regulation reserves



Study	Penetration	Regulation
NY 2005	3,300 MW in 33,000 MW peak	36 MW
CA/CEC 2006	12,500 MW in 64,300 MW peak	20 MW up 20 MW down
CAISO 2007	12,500 MW in 64,300 MW peak	130 MW up 400 MW down
ERCOT 2008	15,000 MW in 65,000 MW peak	54 MW up 48 MW down
APS	1,300 MW in 7,905 MW peak	6.2 MW
MN 2006	5,689 MW in 18,527 MW peak	20 MW

Study Conclusions

- Most studies to date have not found physical reliability issues with integrating up to 20% wind
- New flexible thermal generation in some cases may need to be built to help integration
- Fast (5-min) markets help economically integrate wind
- Large balancing areas or cooperation between balancing areas can reduce the affect by spreading the variability out and having more tools to accommodate
- Wind forecasting shows tremendous benefits, a perfect wind forecast shows marginal benefits from state-of-the-art today
- Some studies show benefits of new emerging technologies like storage and demand response

EWITS and WWSIS: Studies of Today

- EWITS and WWSIS are of the largest studies of their kind and they are studying the highest wind penetrations
- The stakeholder participation between all the utilities and ISOs provides tremendous value
- The wind modeling data from the studies have been made public and can be used for a variety of purposes
- New methods of calculating reserve levels are being developed
- Results thus far are not showing anything abnormal
  - Expected finalized reports: EWITS Oct 09, WWSIS Feb 10

Evolution: Studies of the Future

- Each study seems to learn off the last one
- Having a technical review committee with folks who have been on past studies prevents lots of issues
- With very high penetrations of wind power the planning and operations of the system may change
  - EWITS is pursuing a sensitivity study to evaluate advanced unit commitment techniques, many European studies have done the same
- There seems to be no consistent method in calculating what reserves are needed in studies
  - Wind is much different than contingency events
- Optimizing what the resource mix is and what resources help the system the most
  - Studies that include new technologies like CAES, PHEV will be needed

Conclusion

- Wind power integration studies are performed to help operators and planners prepare for large penetrations of wind
- The studies have many different components that include a gathering of massive amounts of data, scenario development, and many different pieces of analysis
- Numerical results differ by system but conclusions of the study tend to be similar
- The studies have progressed over time and good ideas are passed on study to study
- Further evolution is seen and new challenging problems will be solved

Questions and Comments

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www.uwig.org

www.nrel.gov/wind/systemsintegration

Ela, Milligan, Parsons, Lew, and Corbus. “The Evolution of Wind Power Integration Studies: The past, present, and future” IEEE PES GM Conference Paper, July 2009.