Stochastic Unit Commitment Modeling: Implementation and Market Implications

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Federal Energy Regulatory Commission
Washington, DC, June 3, 2010

Outline

- Introduction
- Implementation and market implications
- Stochastic unit commitment in market operations – a numerical example
- Concluding remarks

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Stochastic Unit Commitment

- What is stochastic unit commitment?
  - Scenario-based uncertainty representation in the unit commitment formulation
  - The objective is to minimize the expected cost

- Why stochastic unit commitment?
  - Uncertainty and variability in wind and solar power
  - Electric vehicles: uncertain charging/discharging patterns and unclear business model
  - Other uncertainties

- How is stochastic unit commitment being used?
  - Generally used as a planning tool
  - An existing model: WILMAR(Wind Power Integrating in Liberalized Electricity Markets)
  - The Irish system operator is trying to use WILMAR as an operational tool

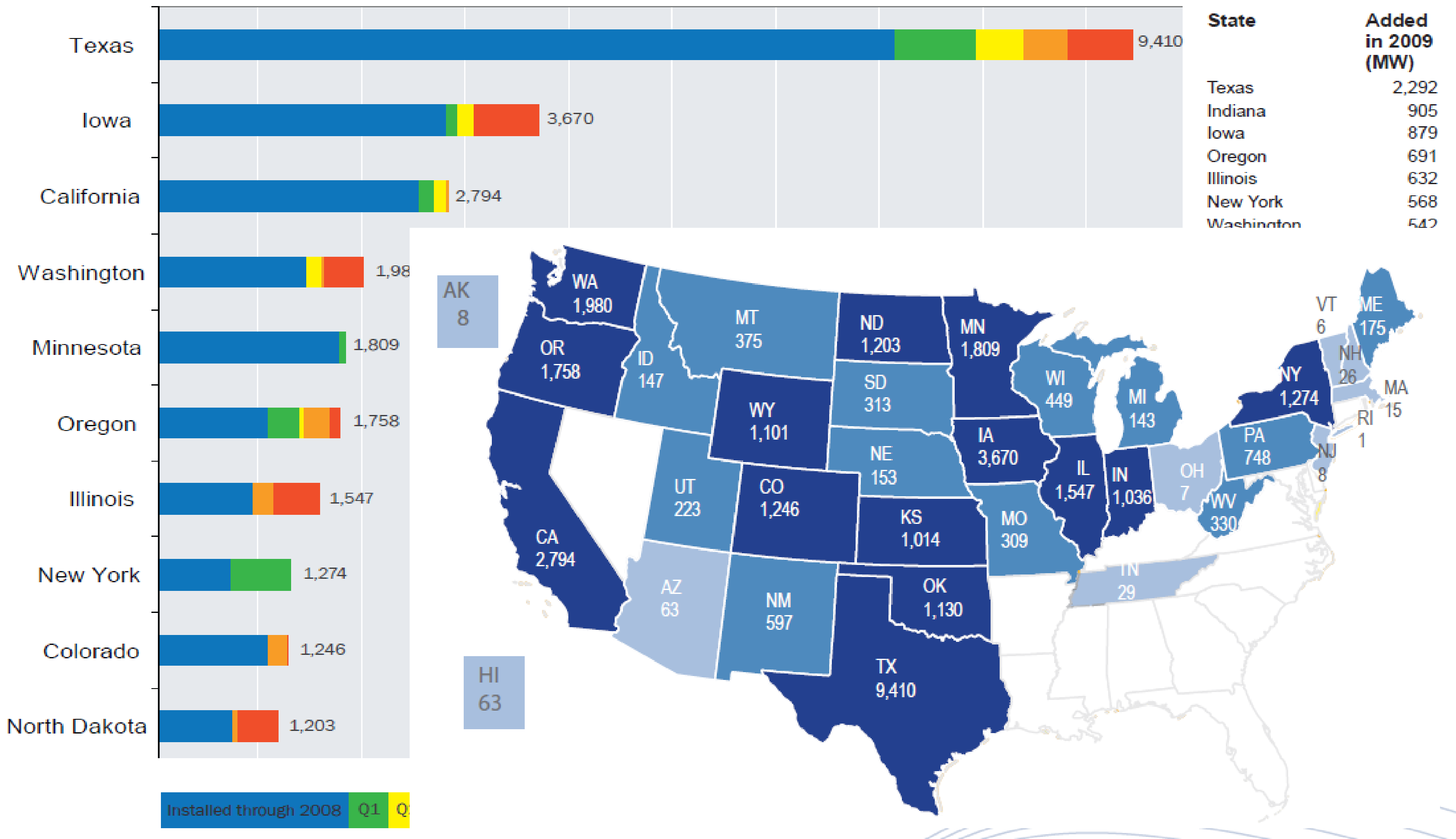
- How can we implement stochastic unit commitment in the market?
  - Day ahead UC? Reliability UC? Intra-day UC?

Taking Wind as an Example

Wind Project Installations by State (Top Ten States)

Source: AWEA 2010

State	Added in 2009 (MW)
Texas	2,292
Indiana	905
Iowa	879
Oregon	691
Illinois	632
New York	568
Washington	542

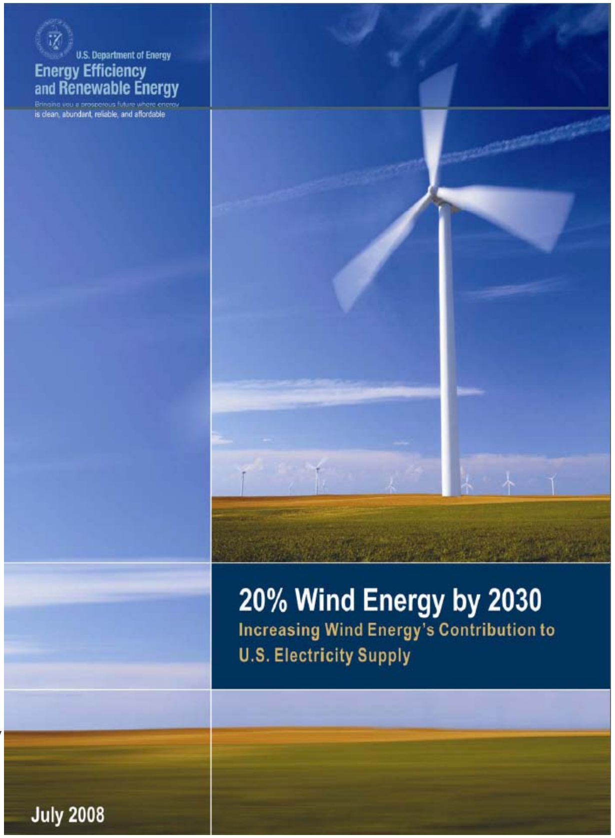


DOE’s 20% Wind by 2030 Report

- Explores “*a modeled energy scenario in which wind provides 20% of U.S. electricity by 2030*”

- Describes *opportunities and challenges* in several areas
  - Turbine Technology
  - Manufacturing, materials, and jobs
  - *Transmission and integration*
  - Siting and environmental effects
  - Markets

- Enhanced *wind forecasting* and *better integration* into system operation is one of the key challenges
  - This is also emphasized by North American Electric Reliability Council in a recent report (NERC, 2009)



Project: "Development and Deployment of Advanced Wind Forecasting Techniques"

Goal: To contribute to efficient large-scale integration of wind power by developing improved wind forecasting methods and better integration of advanced wind power forecasts into system and plant operations.

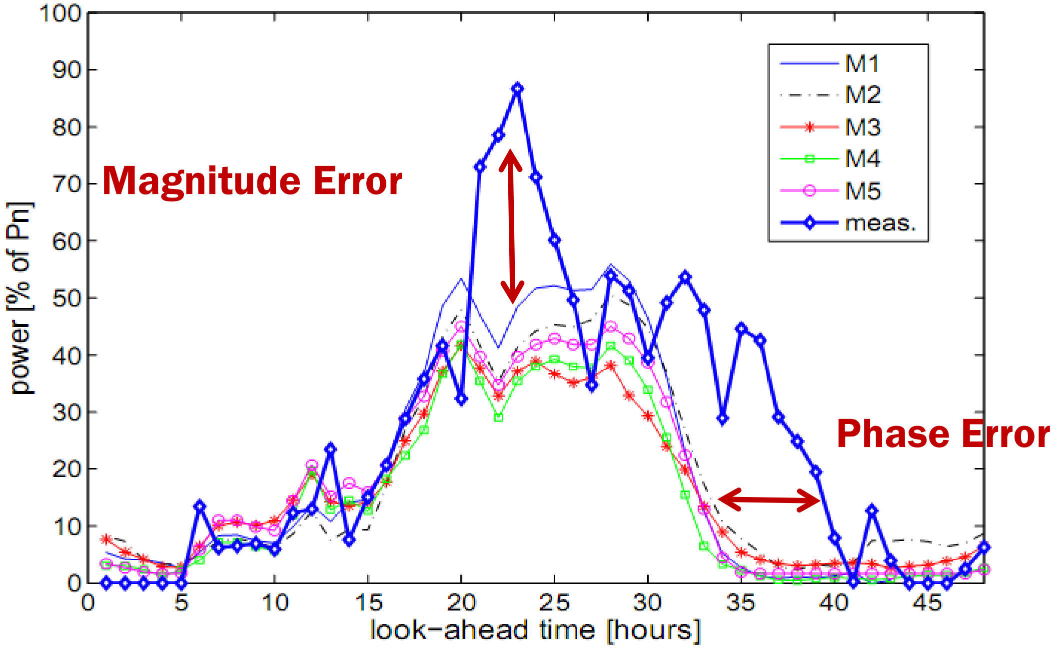
Collaborator:	Institute for Systems and Computer Engineering of Porto (INESC Porto), Portugal
Industry Partners:	Horizon Wind Energy and Midwest ISO (MISO)
Sponsor:	U.S. Dept. of Energy (Wind and Water Power Program)

The project consists of two main parts:

- Wind power forecasting
  - Review and assess existing methodologies
  - Develop and test new and improved algorithms
- Integration of forecasts into operations (power system and wind power plants)
  - Review and assess current practices
  - Propose and test new and improved approaches, methods and criteria
- Project website: http://www.dis.anl.gov/projects/windpowerforecasting.html

Wind Power Forecast Errors

- Error depends on several factors
  - Prediction horizon
  - Time of the year
  - Terrain complexity
  - Model inputs and model types
  - Spatial smoothing effect
  - Level of predicted power



Error sources:

- Error in meteorological forecasts
- Errors in wind-to-power conversion process
- Errors in SCADA information and wind farm operation

Deterministic vs. Stochastic Approach

- How to deal with *increased* uncertainty in system operation?
  - How to account for load uncertainty, generator outages, and *wind uncertainty* in the commitment of resources?

- Deterministic unit commitment and reserve requirements
  - Traditional approach used in industry
  - Deterministic optimization problem w/reliability constraints
  - Need to revisit current reserve requirements

- Stochastic unit commitment
  - Explicit representation of uncertainty in problem formulation
  - Minimization of *expected costs*

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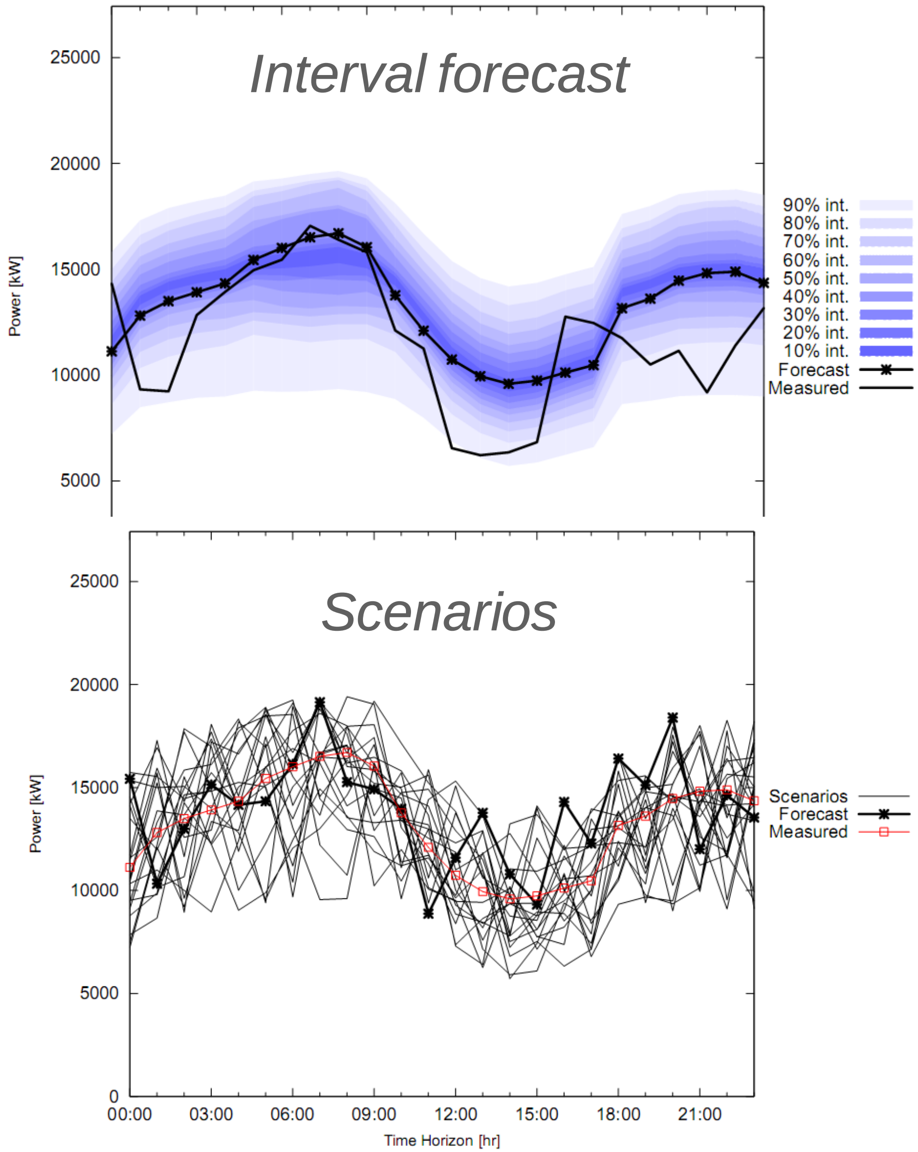
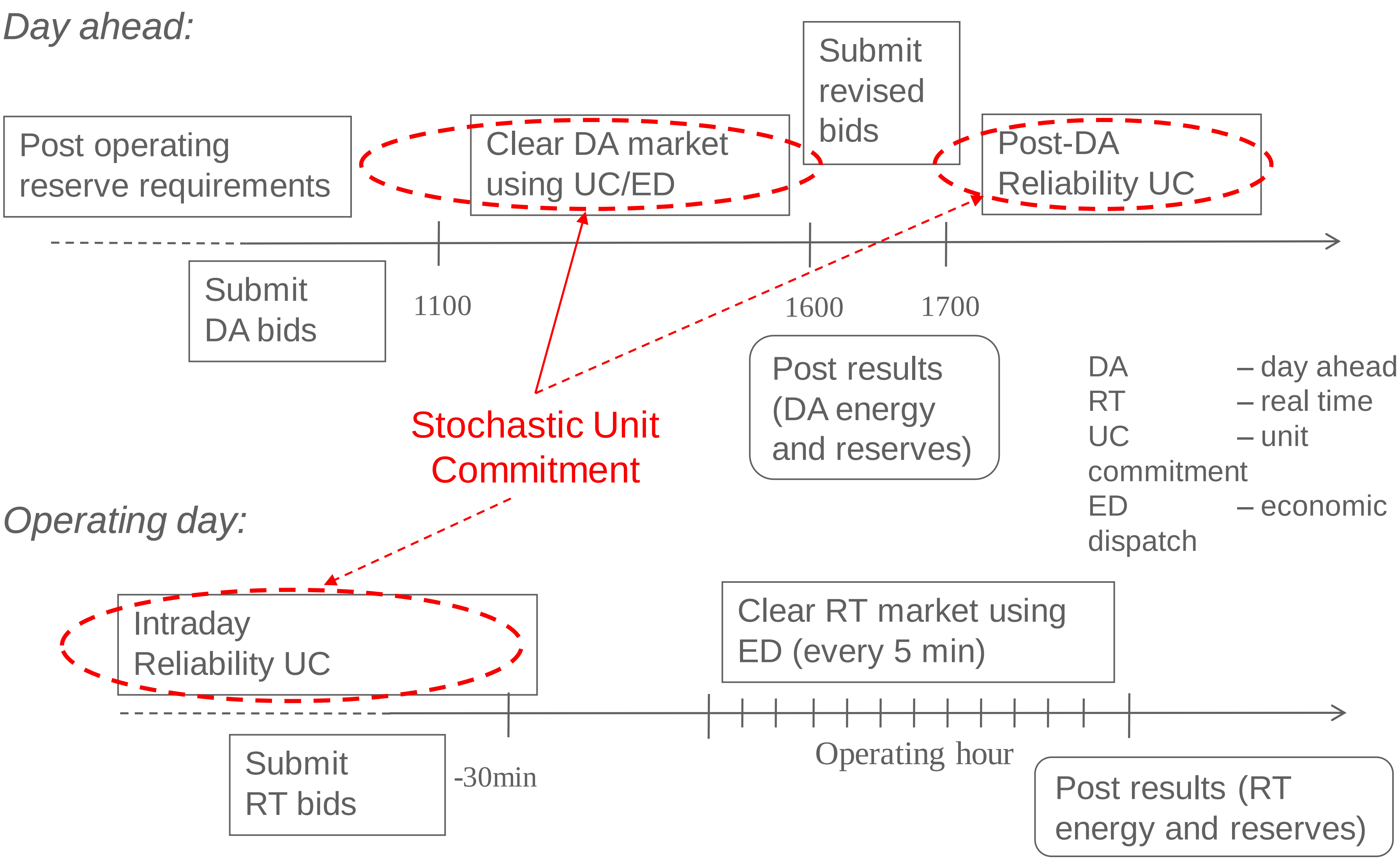
Representing Uncertainty in Wind Power Forecasts

Uncertainty Representation	
Probabilistic	Probability Mass Function
	Probability Density Function
	Quantiles
	Interval Forecasts
Risk Indices	Meteo Risk Index
	Prediction Risk Index
Scenarios of Generation	Scenarios with temporal dependency
	Scenarios with spatial/temporal dependency

Wind Power Forecasting: State-of-the Art 2009



Stochastic Unit Commitment in Market Procedure



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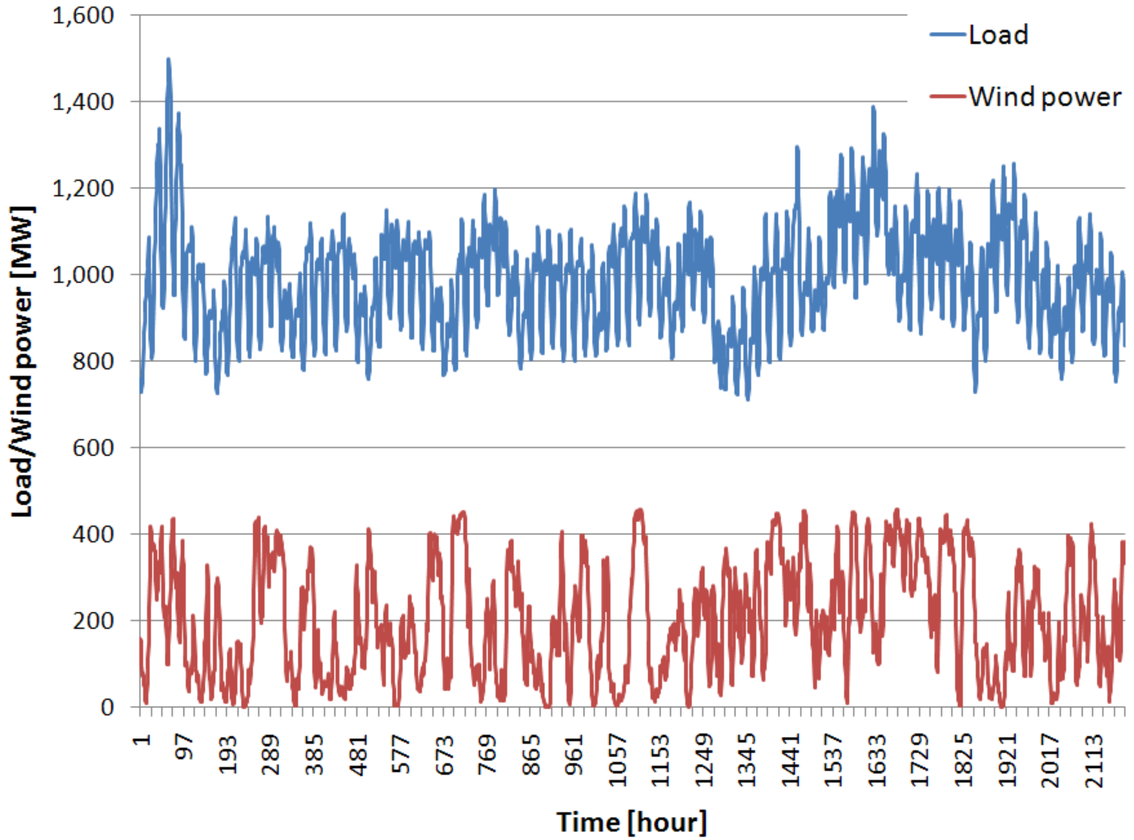
Data

- 10 thermal units: 1662 MW
  - Base, intermediate peak load
- Wind power: 500 MW
  - 2006 wind series from 15 sites in Illinois (NREL EWITS dataset)
  - 20% of load
- Peak load: 1500 MW
  - 2006 load series from Illinois
- No transmission network
- 91 days simulation period



Stochastic Unit Commitment Formulation

Minimize [startup cost + expected (production cost + unserved load cost + unserved reserve cost)]

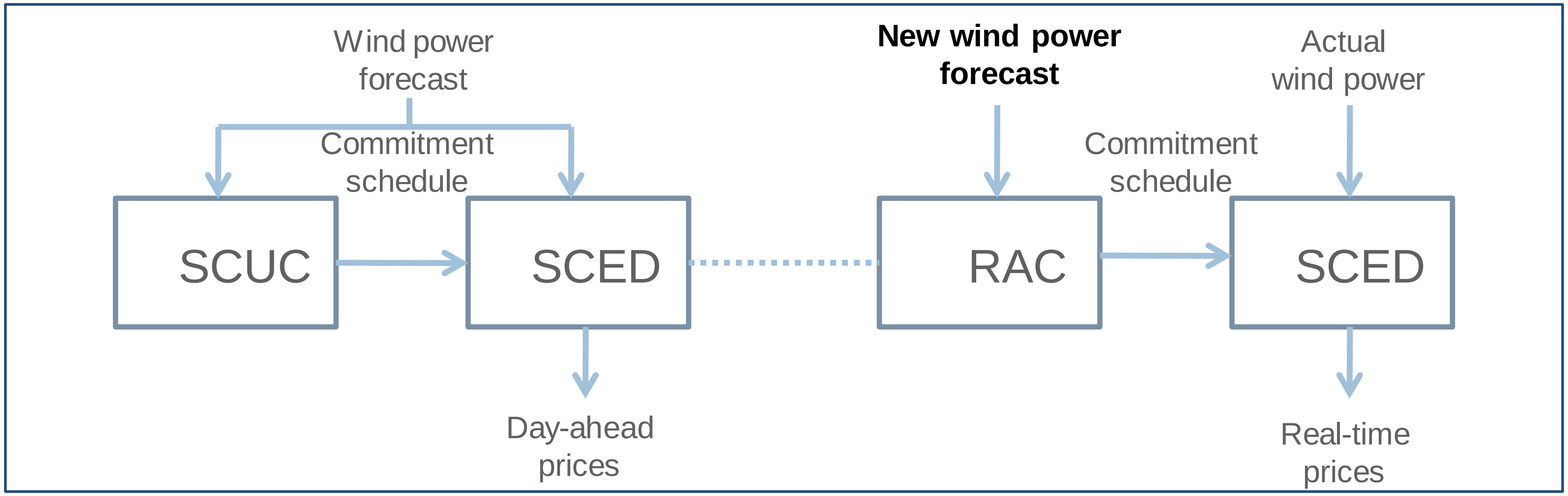
Subject to:

- *Load balance*
- *Reserve margin as function of wind power*
- *Thermal units capacity*
- *Wind power generation*
- *Thermal unit ramping constraints*
- *Min on time*
- *Min off time*

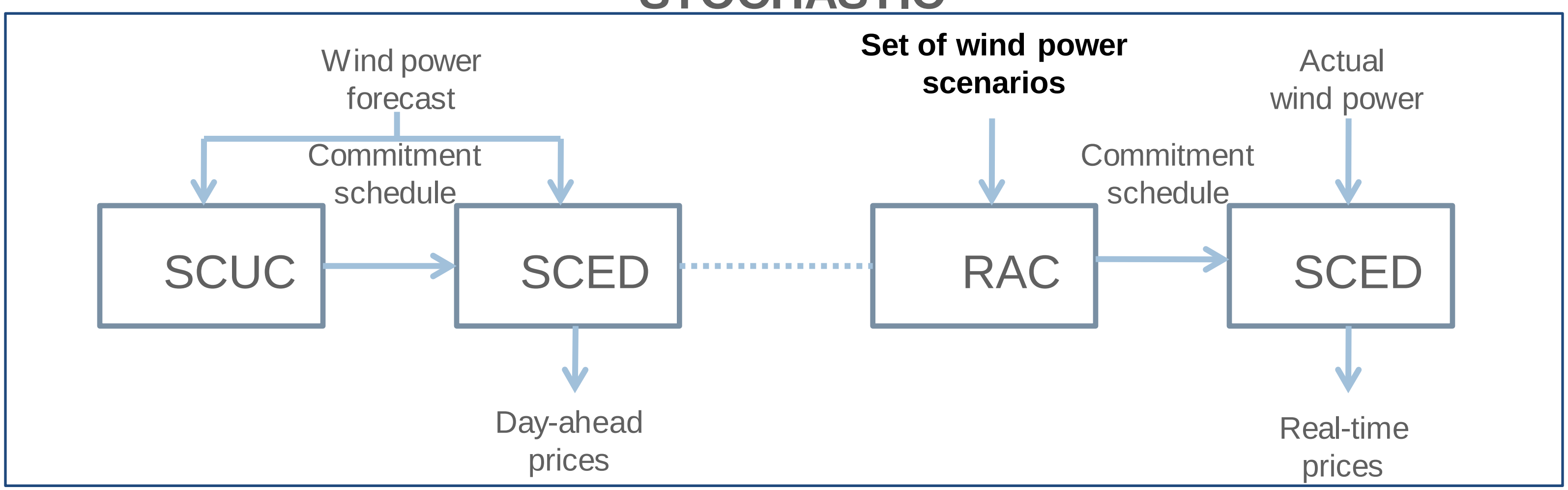
- A two-stage stochastic mixed integer linear programming (MILP) problem
  - First-stage: commitment
  - Second-stage: dispatch

Simulation Modeling Framework

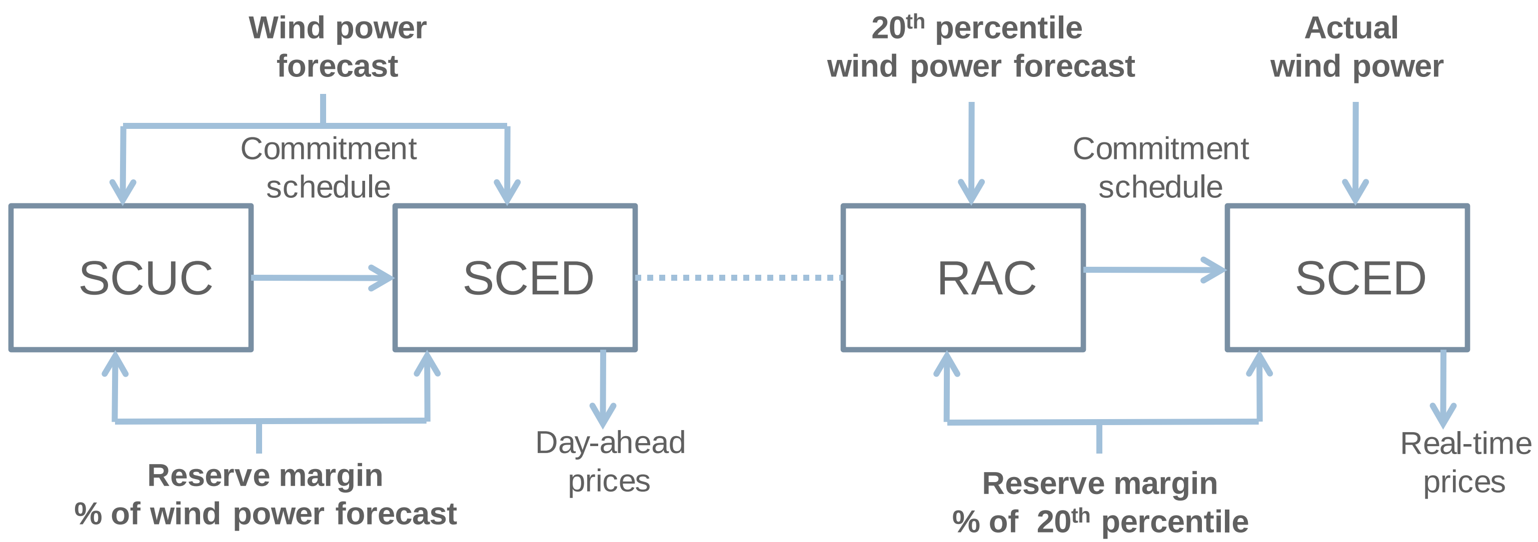
DETERMINISTIC



STOCHASTIC



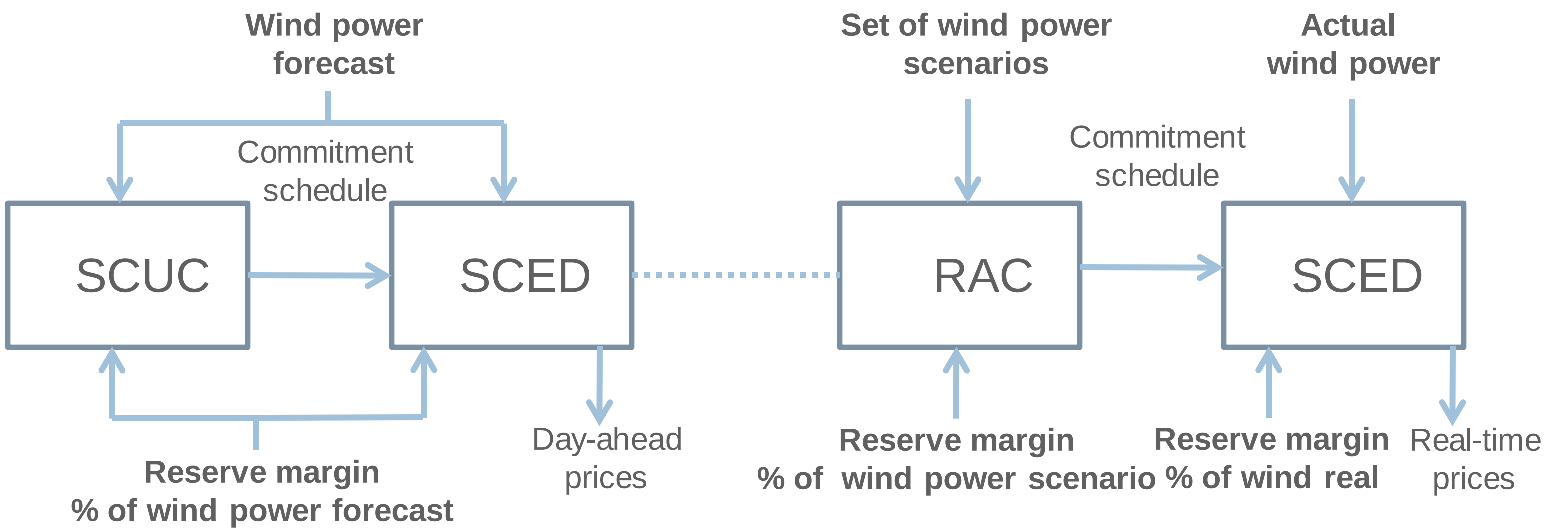
Deterministic Approach: Cases Set Up



Case	SCUC & SCED Reserve margin (%)	RAC & SCED Reserve margin (%)
D0*	20	20
D1	20	20
D2	20	40
D3	40	20
D4	40	40
D5	no reserve	no reserve

*Case D0 uses a perfect forecast

Stochastic Approach: Cases Set Up



Case	SCUC & SCED Reserve margin (%)	RAC & SCED Reserve margin * (%)
S1	20	20
S2	40	20
S3	no reserve	no reserve

*The same percentage of reserve is used in all scenarios

91 Days Simulation – Cost Results

Case	Percentage of Units On-line	Hours of Unserved Load	Unserved Load (MWh)	Unserved Reserve (MWh)	Startup Cost (M$)	Production Cost (M$)	Unserved Load Cost (M$)
D0	23.9	0	0.00	5.5	100.70	34,357.24	0.00
D1	25.1	23	465.87	927.1	110.22	34,538.52	1,630.53
D2	25.8	9	137.37	1,678.6	110.70	34,676.18	480.80
D3	25.1	23	465.87	927.1	109.73	34,537.52	1,630.55
D4	25.8	9	137.37	1,678.6	110.49	34,676.46	480.80
D5	24.5	52	1,556.21	0.0	141.16	34,448.38	5,446.73
S1	30.9	0	0.00	0.0	158.84	35,505.98	0.00
S2	30.9	0	0.00	0.0	160.92	35,511.45	0.00
S3	29.9	0	0.00	0.0	158.43	35,317.24	0.00

Observations:

– More united are committed in the stochastic cases, which also lead to more unit startups and higher production cost

– Zero unserved reserve and load in the stochastic cases

91 Days Simulation – Price Results

Case	Average DA Energy Price ($/MWh)	Average RT Energy Price ($/MWh)	Load-weighted DA Energy Price ($/MWh)	Load-weighted RT Energy Price ($/MWh
D0	26.91	26.91	27.60	27.60
D1	22.84	72.88	23.66	77.83
D2	22.76	64.64	23.56	68.88
D3	22.32	72.88	22.90	77.84
D4	22.76	64.64	23.50	68.89
D5	20.58	103.58	21.04	105.32
S1	22.78	19.97	23.58	20.33
S2	22.79	19.94	23.53	20.30
S3	20.42	20.03	20.90	20.39

Observations:

- In the deterministic cases, real-time prices are higher due to curtailment of load or reserve
- Large differences in real-time prices between the deterministic and stochastic cases
- Prices in the stochastic cases are lower than the deterministic cases because more units are online in the stochastic cases

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Concluding Remarks – Potential and Key Issues

- Stochastic unit commitments shows advantages by scenario representation of uncertainties

- Computational requirements
  - Advanced decomposition method
  - Solver improvement

- Scenarios
  - Quality of scenarios and evaluation criteria
  - Scenario generation
  - Scenario reduction techniques
  - Additional reserves may be needed to accommodate the errors in wind power forecasting even in the stochastic unit commitment

- Market settlement
  - Probability weighted LMP? Or a single LMP?
  - More cost to consumers? More cost to producers?

Questions?

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