Impact of Wind Power Forecasting on Unit Commitment and Dispatch

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Outline

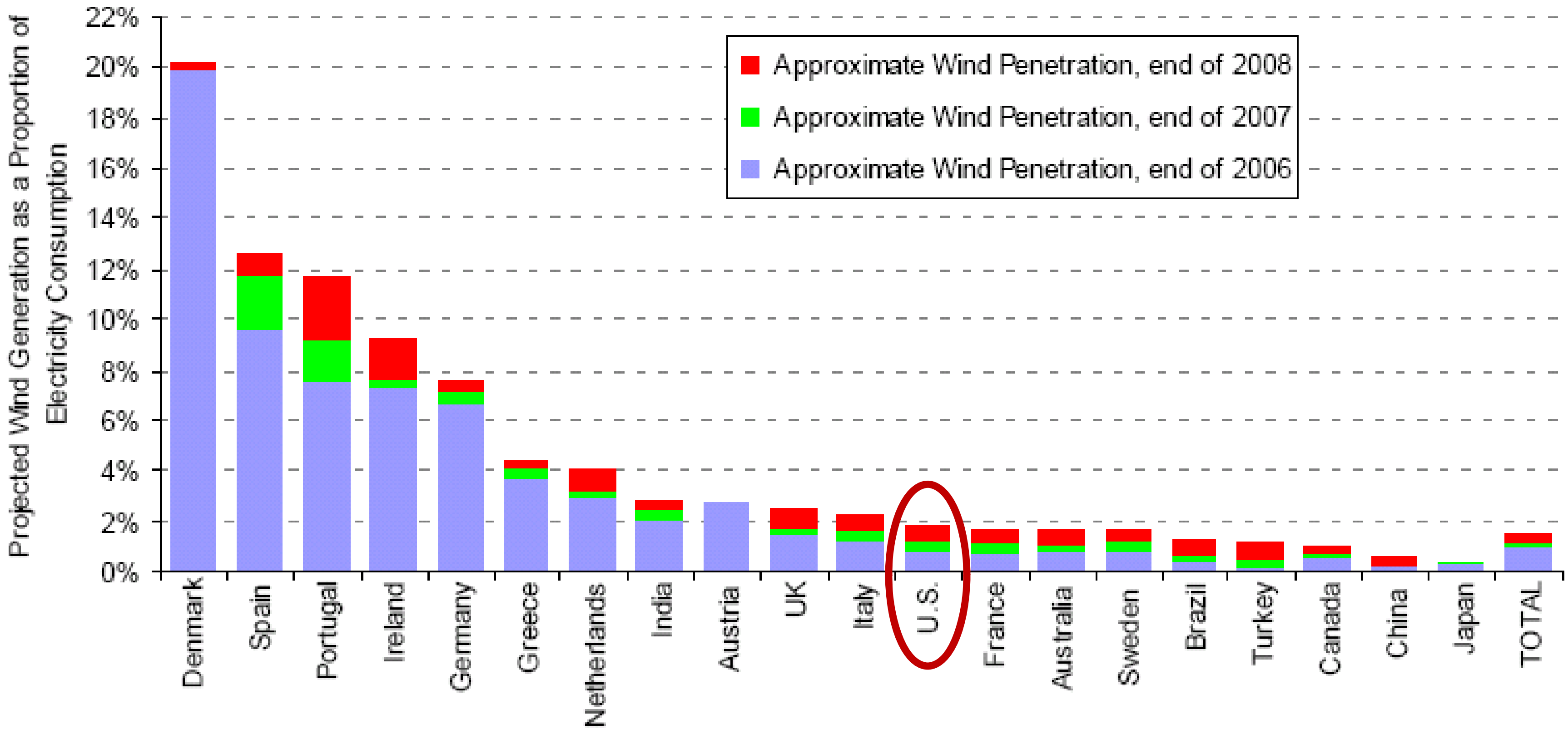
- Background
- Forecasting and electricity market operations
- Stochastic vs. deterministic unit commitment
  - Model description
  - Case study (preliminary)
- Concluding remarks

Increasingly important to make use of the information in wind power forecasts in system and market operations

Stochastic methods can help system/market operators handle increased uncertainty and variability from wind power

Wind Penetration in Selected Countries

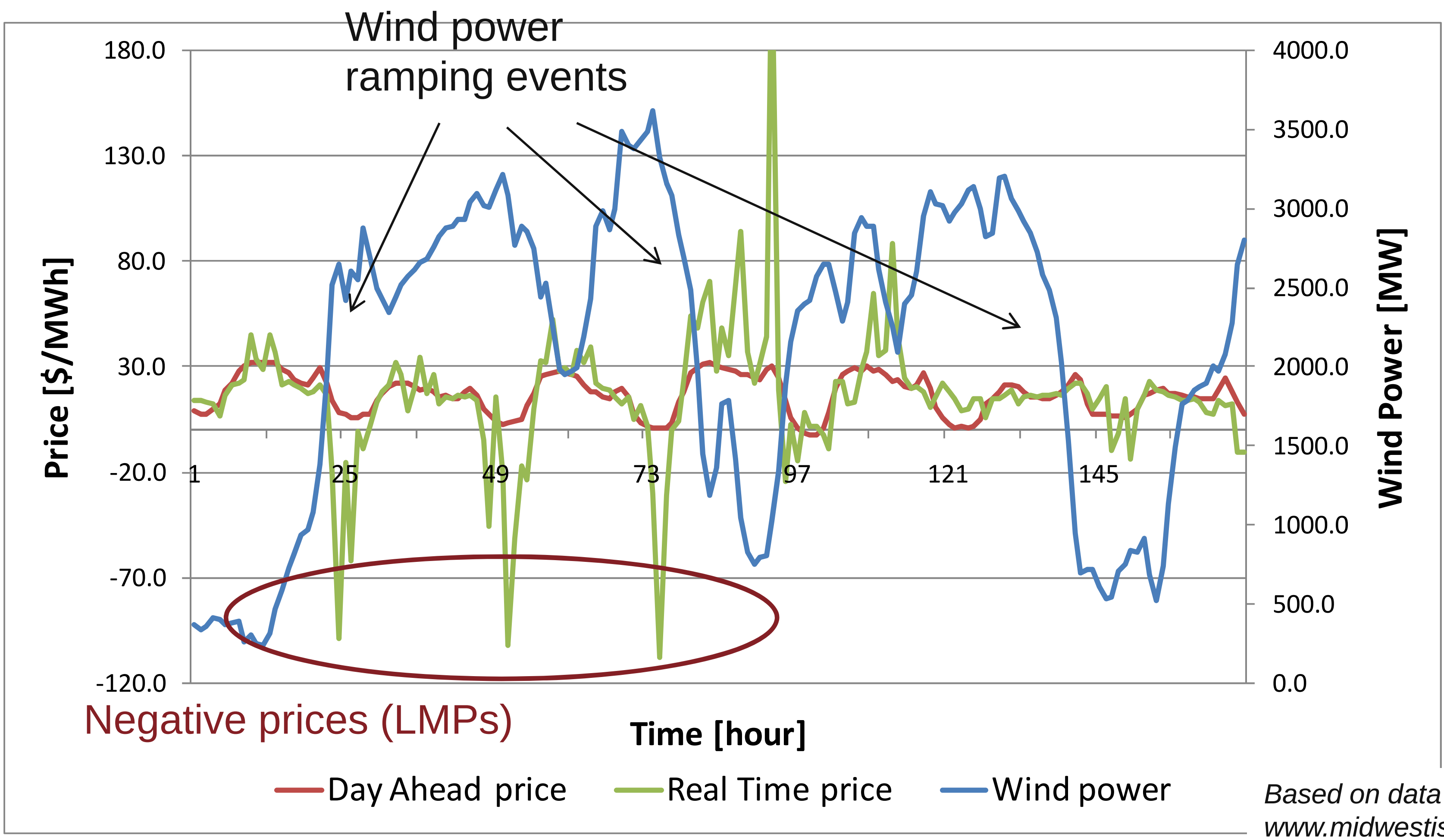
United States recently became the *world leader* in wind power capacity with over 8 GW installed in 2008 and almost 30 GW total installed capacity (*AWEA*)



Source: Berkeley Lab estimates based on data from BTM Consult and elsewhere

Does Wind Power Influence Market Operations?

Midwest ISO Wind Power and MN Hub Prices, May 11-17, 2009:



Based on data from www.midwestiso.org

Our 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.

Collaborators:	Institute for Systems and Computer Engineering of Porto (INESC Porto), Portugal
Industry Partners:	Midwest ISO (MISO) and Horizon Wind Energy
Sponsor:	U.S. Dept. of Energy (Wind and Hydropower Tech. 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 power plants)
  - Review and assess current practices
  - Propose and test new and improved approaches, methods and criteria

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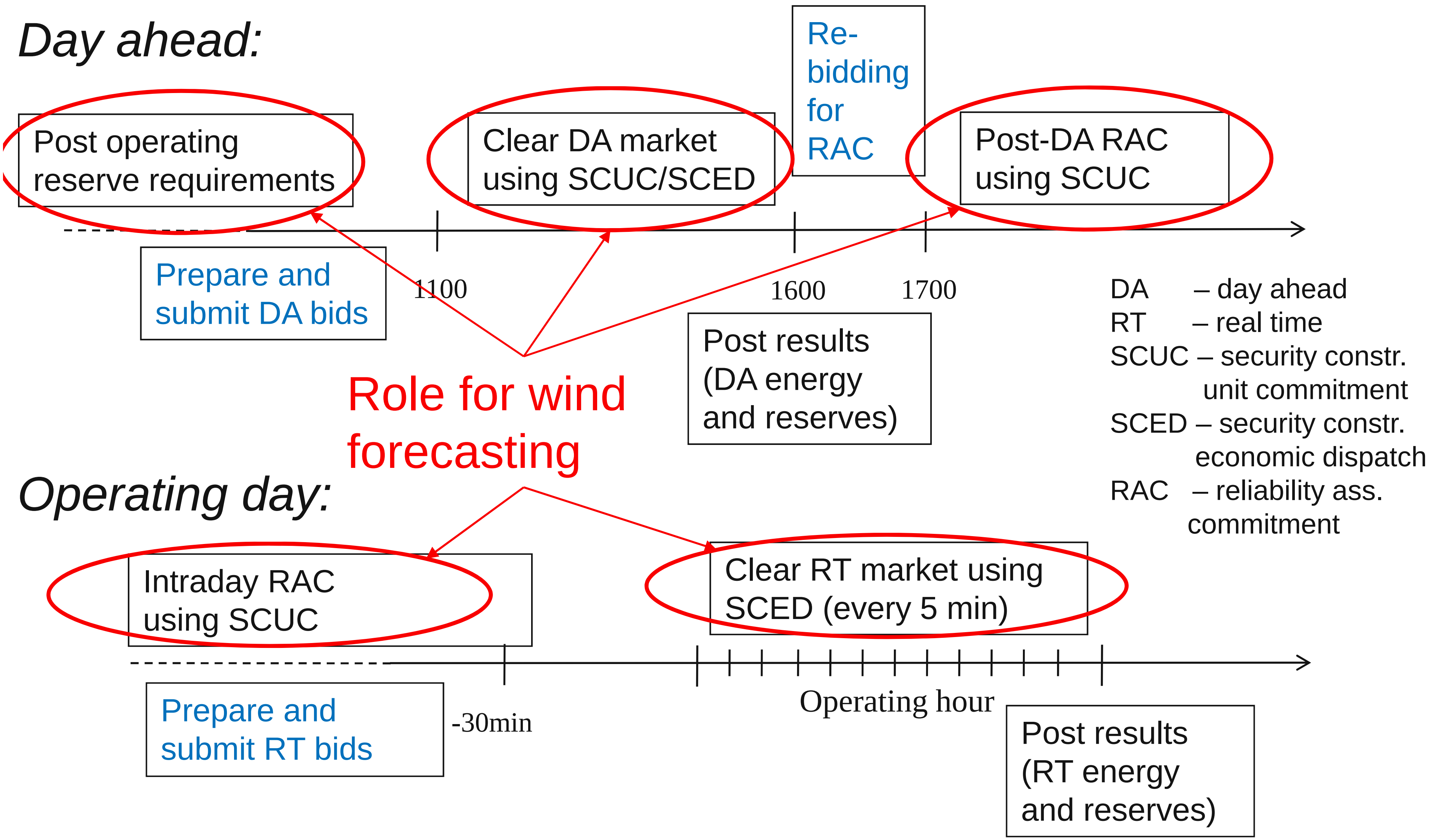
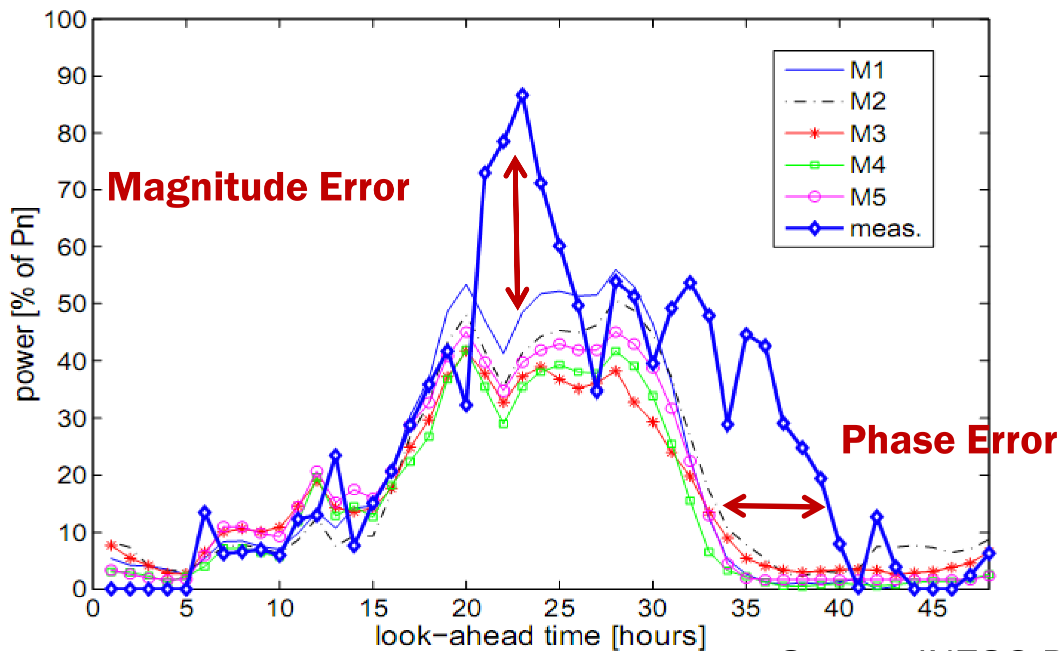
Steps in US Electricity Market Operations (based on Midwest ISO)



Wind Power Forecasts are not Perfect…..



Source: INESC Porto

Error sources:

Error in meteorological forecasts

Errors in wind-to-power conversion process

Errors in SCADA information (wind power and met data)

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

What are the consequences for economics and security?
What is the best way to handle these uncertainties?

Deterministic vs. Stochastic Approach to Operation and Reliability

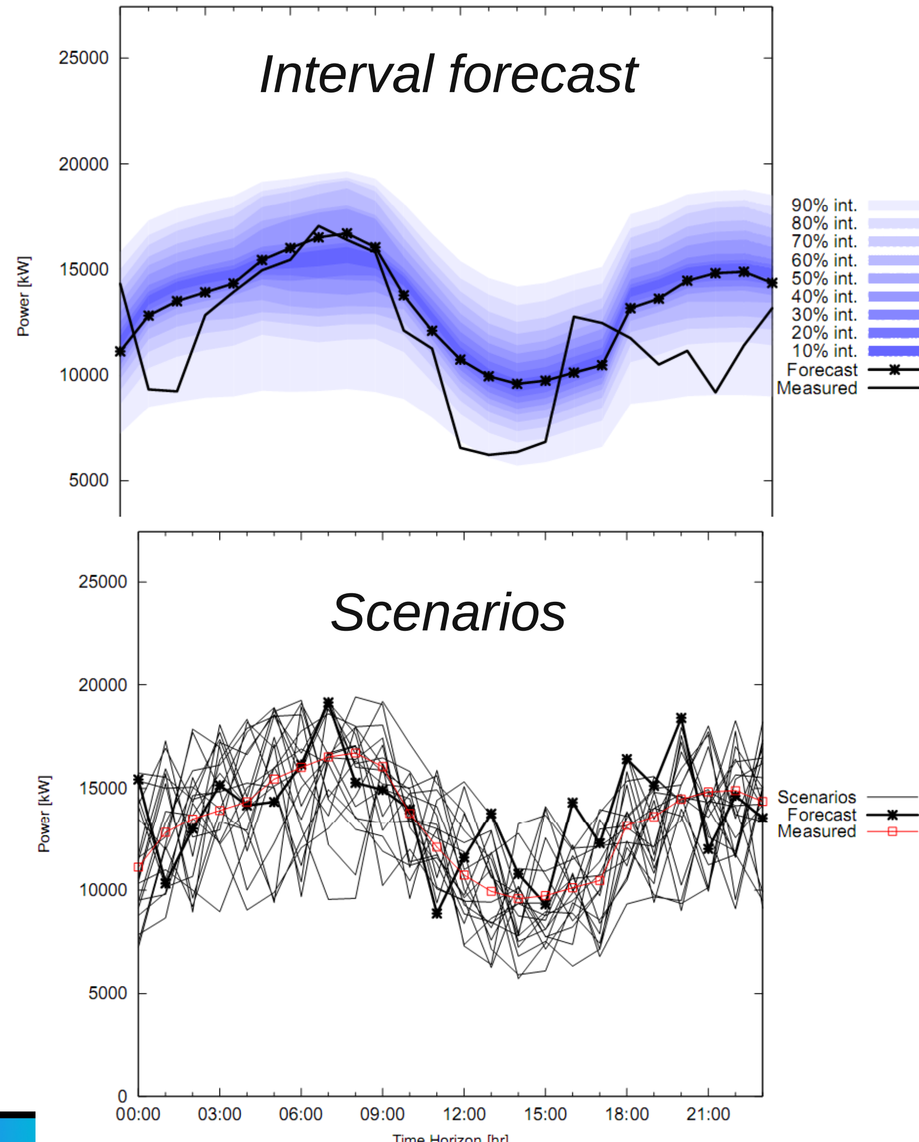
- How to deal with *increased* uncertainty in system operation?
  - How to account for load uncertainty, generator outages, *and wind uncertainty* in the day-ahead unit commitment?

- Deterministic unit commitment and reserve requirements
  - Traditional approach used in industry
  - Deterministic optimization problem w/reliability constraints
  - Solution may deviate from economic optimum
  - *Need to revisit current operating reserve requirements*

- Stochastic unit commitment
  - Explicit representation of uncertainty in problem formulation
  - Minimization of *expected costs*
  - May become computationally too intensive
  - *Increasing relevance due to additional uncertainty from wind power*

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



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A Stochastic Unit Commitment (UC) Model w/Wind Power Uncertainty

- Formulation using wind power forecast scenarios (s) w/probabilities ($prob_s$):

$$Min \sum_{s=1}^{S} prob_s \times \left\{ \sum_{k=1}^{K} \sum_{j=1}^{J} c_j^{p,s}(k) + \sum_{k=1}^{K} C_{ens} \times ens^s(k) \right\} + \sum_{k=1}^{K} \sum_{j=1}^{J} [c_j^u(k)]$$

Objective function (min expected cost)

$$\sum_{i=1}^{I} pw_i^s(k) + \sum_{j=1}^{J} pt_j^s(k) = D(k) - ens^s(k) \quad , \quad \forall k, \forall s$$

Energy balance

$$\sum_{j=1}^{J} \left[\overline{pt}_j^s(k) - pt_j^s(k) \right] \geq R(k) \quad , \quad \forall k, \forall s$$

Reserve requirements (spinning)

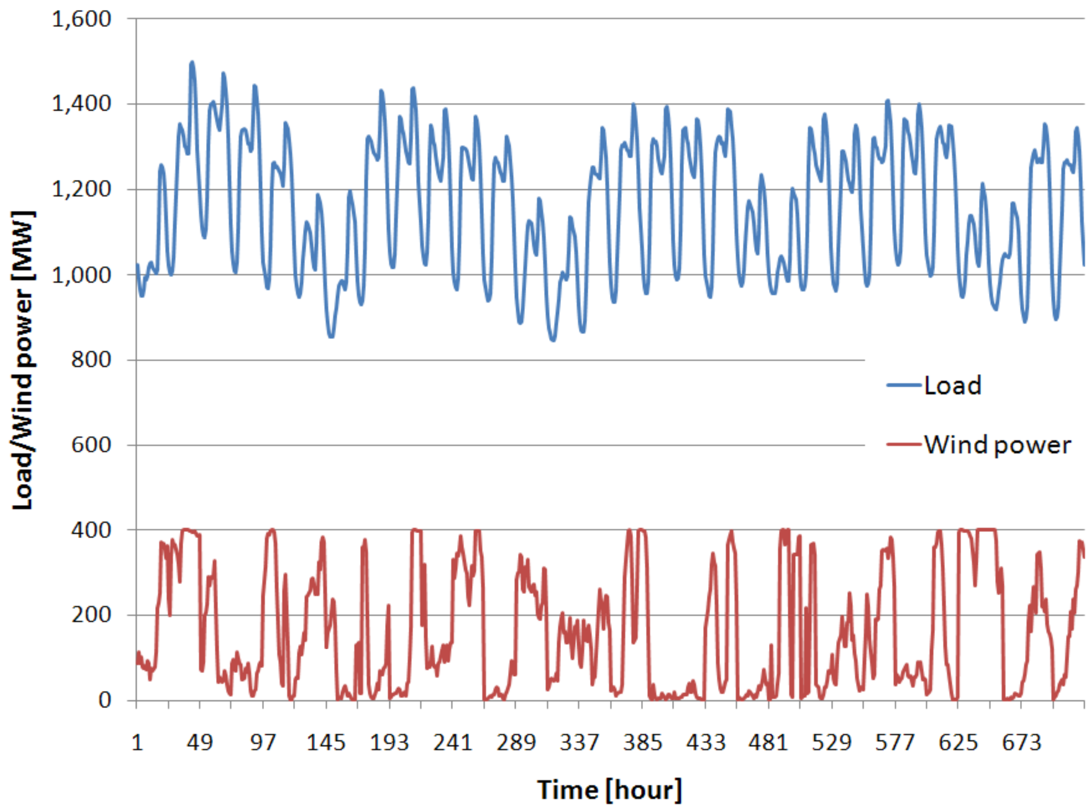
$$p_j(k) \in \pi_j(k) \quad , \quad \forall j, \forall k$$

Unit commitment constraints (ramp, min. up/down)

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

Case Study Assumptions

- 10 thermal units
  - Base, intermediate peak load
  - Total capacity: 1662 MW
- Wind power capacity: 400 MW
- Peak load: 1500 MW
- No transmission network
- 30 days simulation period
  - Day-ahead unit commitment w/wind power forecast
  - Real-time dispatch w/realized wind power generation



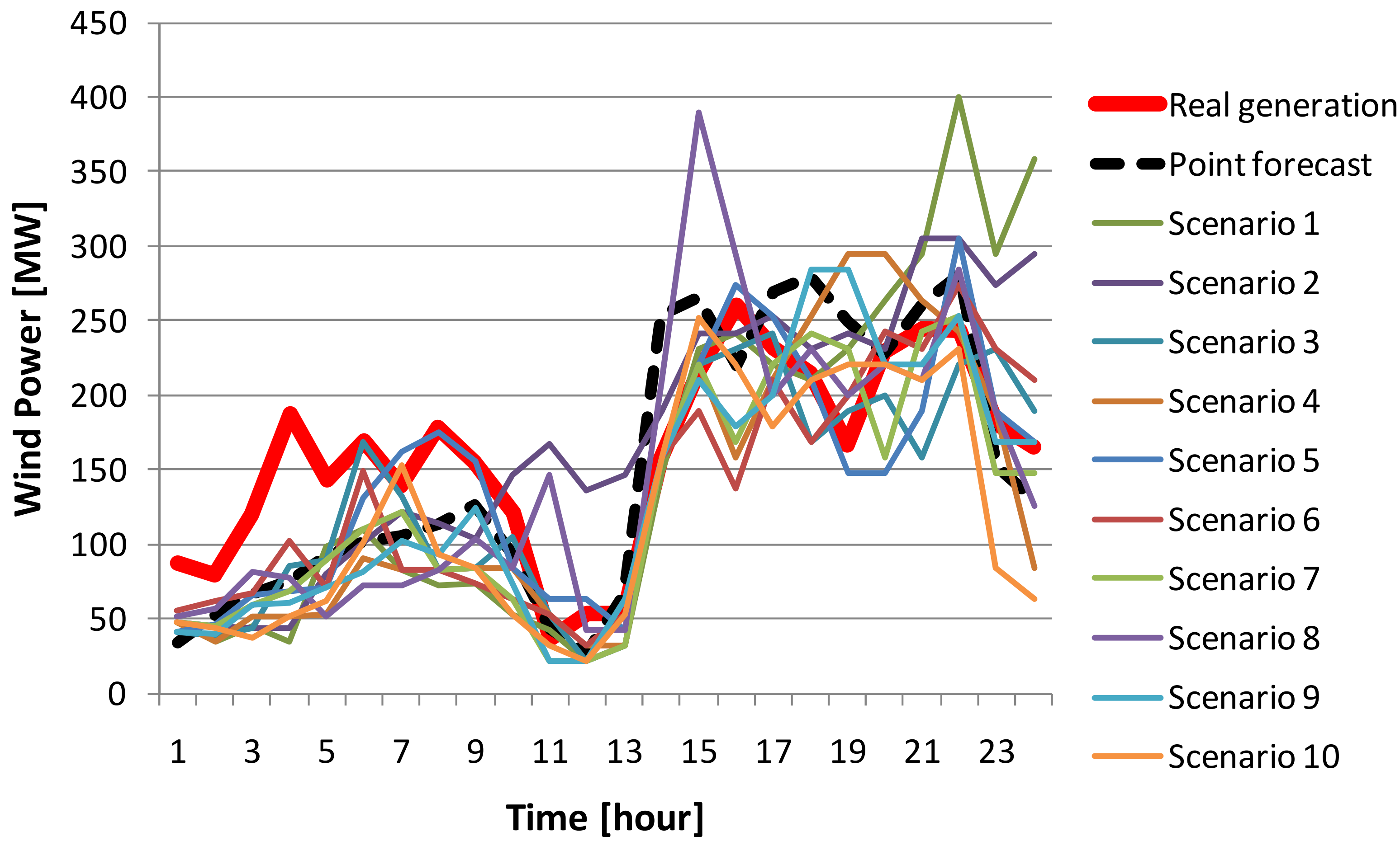
Simulated Cases

- Comparing four deterministic and two stochastic unit commitment strategies

Case	*Unit Commitment*	*Wind Power Forecast*	*UC Reserve Requirement**
D1	Deterministic	Perfect	10%
D2	**Deterministic**	**Point**	**10%**
D3	**Deterministic**	**Point**	**15%**
D4	Deterministic	No	10%
S1	**Stochastic**	**Scenarios**	**10%**
S2	Stochastic	Scenarios	8%

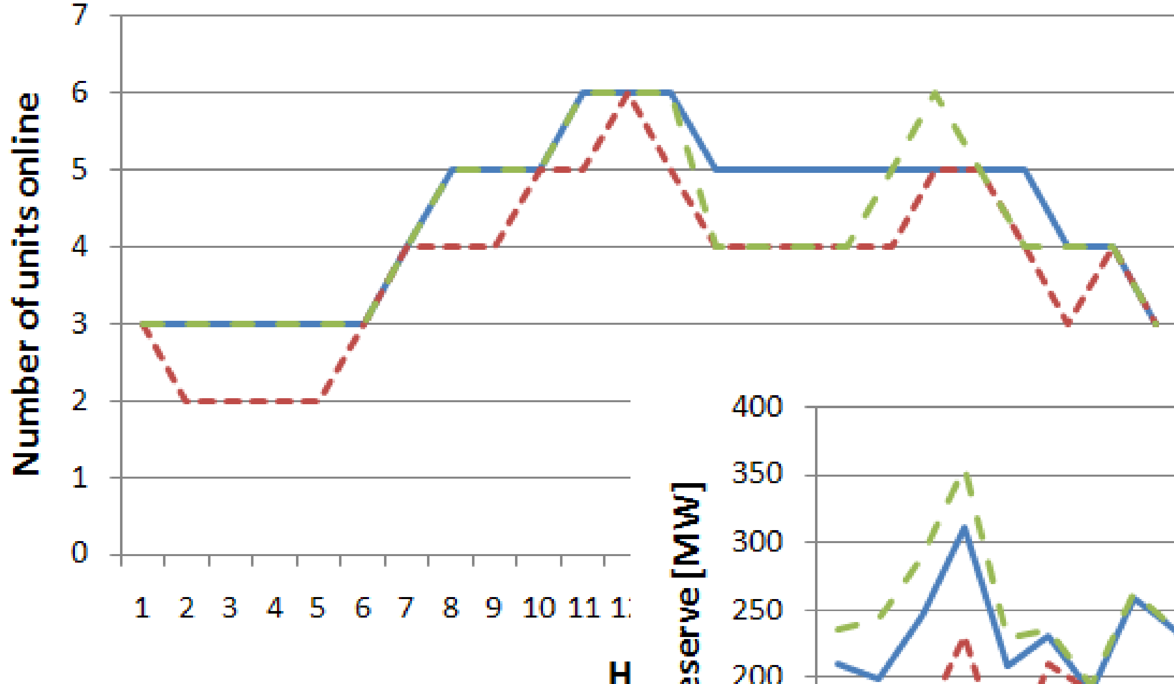
** Reserve requirement kept at 10% in real-time dispatch for all cases, to handle other contingencies.*

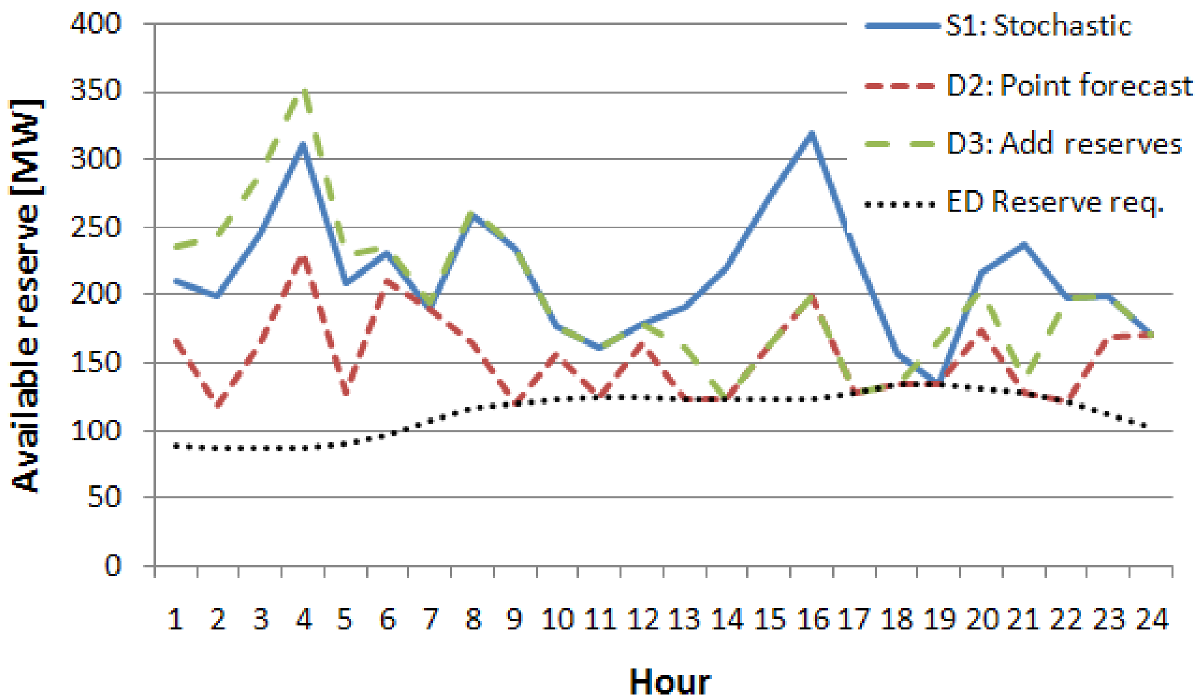
Example of Wind Power Forecast (Day 15)



Note: forecast error (point forecast) < average forecast error (scenarios)

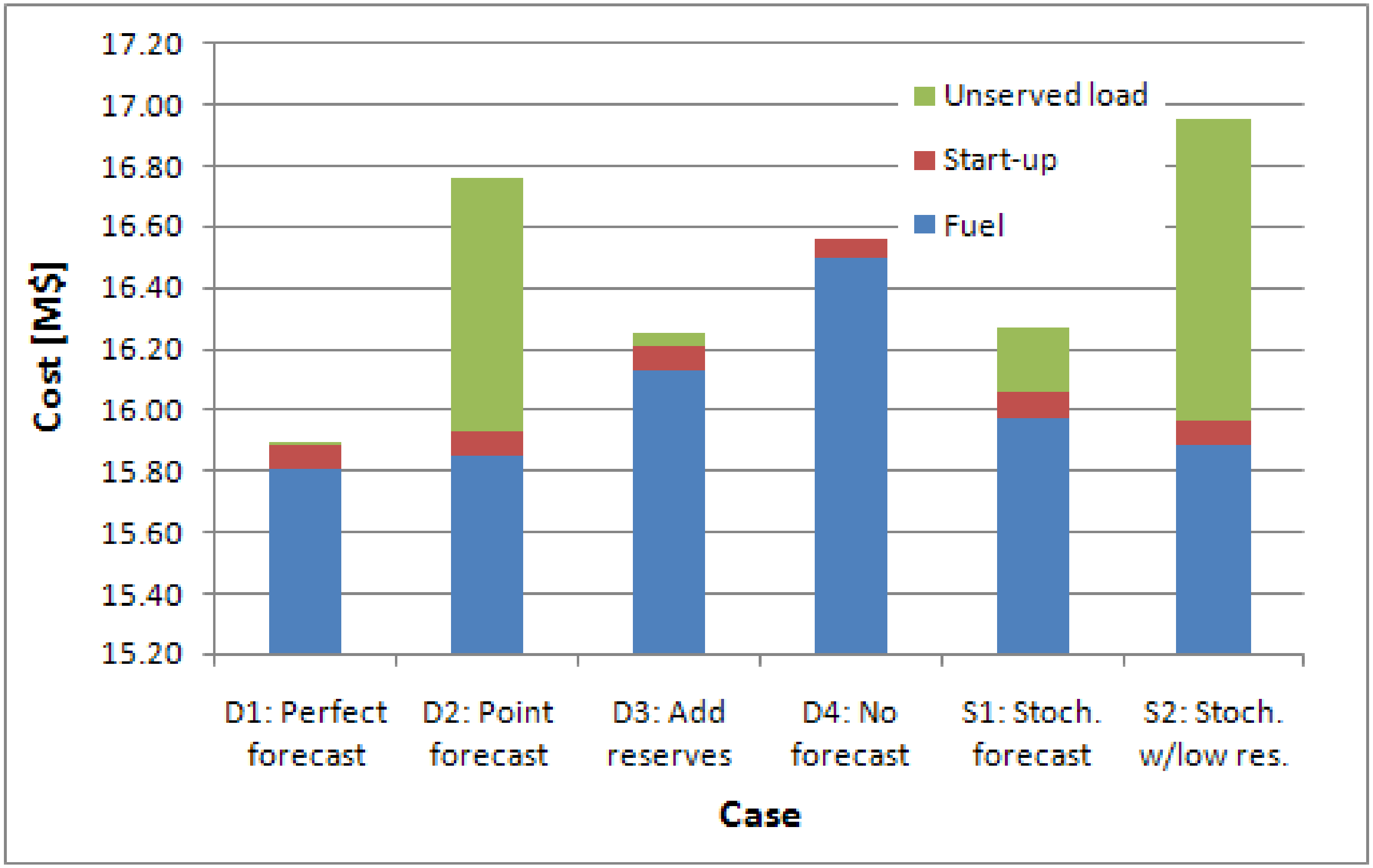
Results: Thermal Commitment and Realized Reserves (Day 15)





- *Stochastic UC gives higher commitment and more available operating reserves*
- *Similar result for deterministic UC w/additional reserve requirement*

Comparison of Costs (30 day simulation)



- *The potential value of forecasting illustrated by perfect forecast (D1)*
- *Deterministic UC with point forecast (D2) appears too risky*
- *Deterministic UC w/add reserves (D3) and stochastic UC (S2) give similar total cost*

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Summary of Other Results (30 days simulation)

Scenario	No. of start-ups	Avg. Avail. Reserve [MW]	Avg. Energy Price [$/MWh]
D1	165	162.5	30.5
D2	163	175.6	80.1
D3	197	214.3	29.5
D4	154	281.5	25.1
S1	190	191.0	43.5
S2	199	178.5	123.1

- *Stochastic unit commitment tends to give more start-ups*
- *Available operating reserves in real-time highest in scenarios D3 and D4*
- *Unit commitment policy has huge impact on prices*

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Model and Case Study: Preliminary Conclusions and Future Work

- Preliminary conclusions
  - Wind power forecasting is important
  - Stochastic unit commitment shows potential
  - The interaction between reserve requirements and UC strategy must be further investigated

- Future work
  - Longer UC horizon
  - Unit re-commitment between day-ahead and real-time
  - Transmission constraints and locational prices
  - Demand response
  - Analysis of financial settlement (energy and ancillary services)
  - Alternative ways of generating forecast scenarios
  - Case study with real-world data

Key Challenges for Wind Power Forecasting and Market Operation

- Improved wind power forecasting models
  - Improved point forecasts
  - Generating consistent and reliable *wind power uncertainty* forecasts
  - Forecasting *ramping events*

- Improved use of wind power forecasting into market operation
  - Integrate the wind power forecast into operating procedures and tools (reserve requirements, unit commitment and dispatch models)
  - Make efficient use of *uncertainty information* in wind power forecast in system operations: *stochastic methods to commitment and dispatch*
  - Market incentives for wind power: Wind power bidding, dispatch, curtailment, control (energy and ancillary services)

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