Wind Integration Analysis

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Presented by John Kueck

ORNL Power System Reliability, Restructuring & Ancillary Services Expertise Applied To Wind Integration Issues

- **As wind energy matures and thousands of MW are installed wind and power system interactions become increasingly important**
- **Multiple issues**
  - **Power system reliability**
  - **Cost impact to wind and the power system**
- **Analysis effort fully integrated with NREL**
  - **Brian Parsons, Michael Milligan, etc.**

Technical Issues

- **Integration cost analysis**
  - **Meso-scale modeling**
  - **Analysis techniques**
- **Sub-hourly movement of conventional generators**
  - **Critical to reducing integration costs**
- **Large ramp events**
  - **Typically not contingency events**
- **Reactive support and dynamic vars**
- **Voltage ride through**
- **Transmission access & transmission availability**

Wind Integration Publications

- R. Zavadil, N. Miller, A. Ellis, E. Muljadi, E. Camm, and, B. Kirby, 2007, *Queuing Up*, IEEE Power & Energy Magazine, November/December
- M. Milligan, B. Kirby, 2007, *The Impact of Balancing Areas Size, Obligation Sharing, and Ramping Capability on Wind Integration*, American Wind Energy Association, WindPower 2007, June
- Y. Wan, M. Milligan, B. Kirby, 2007, *Impact of Energy Imbalance Tariff on Wind Energy*, American Wind Energy Association, WindPower 2007, June
- B. Kirby, 2007, *Evaluating Transmission Costs and Wind Benefits in Texas: Examining the ERCOT CREZ Transmission Study*, The Wind Coalition and Electric Transmission Texas, LLC, Texas PUC Docket NO. 33672, April
- B. Kirby, M. Milligan, E. Wan, 2006, *Cost-Causation-Based Tariffs for Wind Ancillary Service Impacts*, American Wind Energy Association, WindPower 2006, June
- M. Milligan, H. Shiu, B. Kirby, K. Jackson, 2006, *A Multi-year Analysis of Renewable Energy Impacts in California: Results from the Renewable Portfolio Standards Integration Cost Analysis*, American Wind Energy Association, WindPower 2006, June
- H. Shiu, M. Milligan, B. Kirby, K. Jackson, 2005, *California Renewables Portfolio Standard Renewable Generation Integration Cost Analysis: Multi-Year Analysis Results And Recommendations*, The California Energy Commission, December

Many other integration/reliability/restructuring publications that are not exclusively wind

Continued ...

- B. Kirby, M. Milligan, 2005, *A Method and Case Study for Estimating The Ramping Capability of a Control Area or Balancing Authority and Implications for Moderate or High Wind Penetration*, American Wind Energy Association, WindPower 2005, May
- B. Kirby, M. Milligan, Y. Makarov, J. Lovekin, K. Jackson, H. Shiu, 2004, *California RPS Integration Cost Analysis-Phase III: Recommendations for Implementation*, California Energy Commission, July
- B. Kirby, M. Milligan, Y. Makarov, D. Hawkins, K. Jackson, H. Shiu, 2003, *California RPS Integration Cost Analysis-Phase I: One Year Analysis of Existing Resources*, California Energy Commission, December
- B. Parsons, M. Milligan, R. Zavadil, D. Brooks, B. Kirby, K. Dragoon, J. Caldwell, 2003, *Grid Impacts of Wind Power: A Summary of Recent Studies in the United States*, EWEC Wind Energy Journal, June
- B. Parsons, Y. Wan, B. Kirby, 1999, *Wind Farm Power Fluctuations, Ancillary Services, And System Operating Impact Analysis Activities In The United States*, National Renewable Energy Laboratory, Golden CO, July
- R. Hudson, B. Kirby, Y. Wan 2001, *Regulation Requirements for Wind Generation Facilities*, American Wind Energy Association, June
- J. Cadogan, M. Milligan, Y. Wan, and B. Kirby 2000, *Short Term Output Variations in Wind Farms - Implications for Ancillary Services in the United States*, October
- B. Kirby, E. Hirst, B. Parsons, K. Porter, and J. Codagan, 1997, *Electric Industry Restructuring, Ancillary Services, and the Potential Impact on Wind*, American Wind Energy Association, June
- P. Barnes, W. Dykas, B. Kirby, S. Purucker, and J. Lawler 1995, *The Integration of Renewable Energy Sources into Electric Power Transmission Systems*, ORNL-6827, Oak Ridge National Laboratory, Oak Ridge, TN, June

Basic Principals

- **Power system reliability *must* be maintained**
  - **Integrating wind can not degrade reliability**
- **Ancillary services are resources used to maintain reliability – they are often expensive**
  - **Regulation**
  - **Balancing energy (ramping, load following, and changes in unit commitment) Contingency reserves**
  - **Voltage support**
- **Wind should be allocated the increased *cost* of maintaining reliability**
  - **Most of the relationships are nonlinear – wind can not be looked at in isolation**
  - **Use rules and penalties only when cost to differentiate exceed the cost to comply**

Technical Support for Wind Integration Studies

- **Help advance analysis techniques**
  - **Dealing with variability and predictability**
- **Technical support for specific studies**
  - **California**
  - **MISO & Minnesota**
  - **Colorado & Excel**
  - **NY**
  - **Pacific Northwest: current intense effort**
    - **BPA, Idaho Power, Avista, Pacificorp, etc.**

Market Structure Benefits

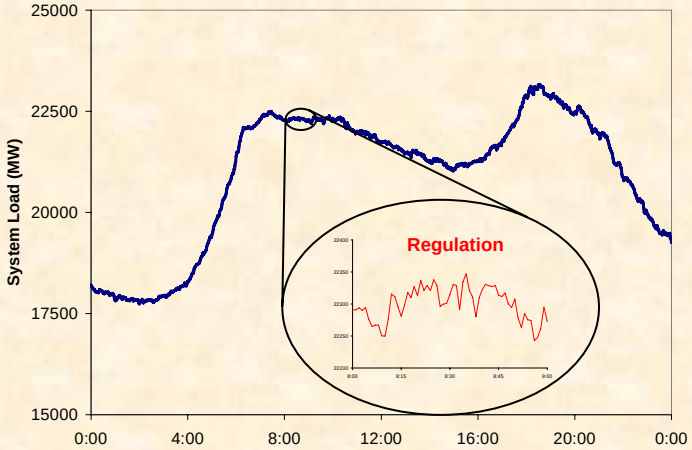
- **Large geographic size**
  - **Aggregation benefits: wind & load**
- **Price transparency**
  - **Value investment**
- **Sub-hourly markets and dispatch**
  - **Access to sub-hourly maneuverability of conventional generators greatly reduces regulation integration costs**

Comparison of Recent Wind Integration Studies

Date	Study	ISO/RTO	Wind Capacity Penetration	Integration Cost: $/MWh of Wind Output	Energy Market Interval
3/05	NYISO	ISO/RTO	10%	Very Low	5 minute
12/06	Minnesota/MISO	ISO/RTO	31%	$4.41	5 minute
2/07	GE/Pier/CAIAP[1]	ISO/RTO	33%	$0-$0.69	10 minute
3/07	Avista	No	30%	$8.84	1 hour
3/07	Idaho Power[2]	No	30%	$16.16	1 hour

[1] Includes 2/3 wind & 1/3 solar and only includes regulation cost increase
[2] Reduced to $7.92 in 9/07 settlement proceedings

Determining Integration Costs



- **Sub-hourly markets vs high regulation requirements**
  - **Is regulation a 10 minute service or a 1 hour+ service?**
- **Regulation consumption tariff**
  - **Allocated to load on *energy* even though some loads consume (vary) much more than others (*not* cost causation – socialized)**
  - **Beginning to see tariffs trying to allocate regulation to wind – initial efforts are really imbalance tariffs**
- **Typically excess ramping capability – load following from sub-hourly energy market at low cost**

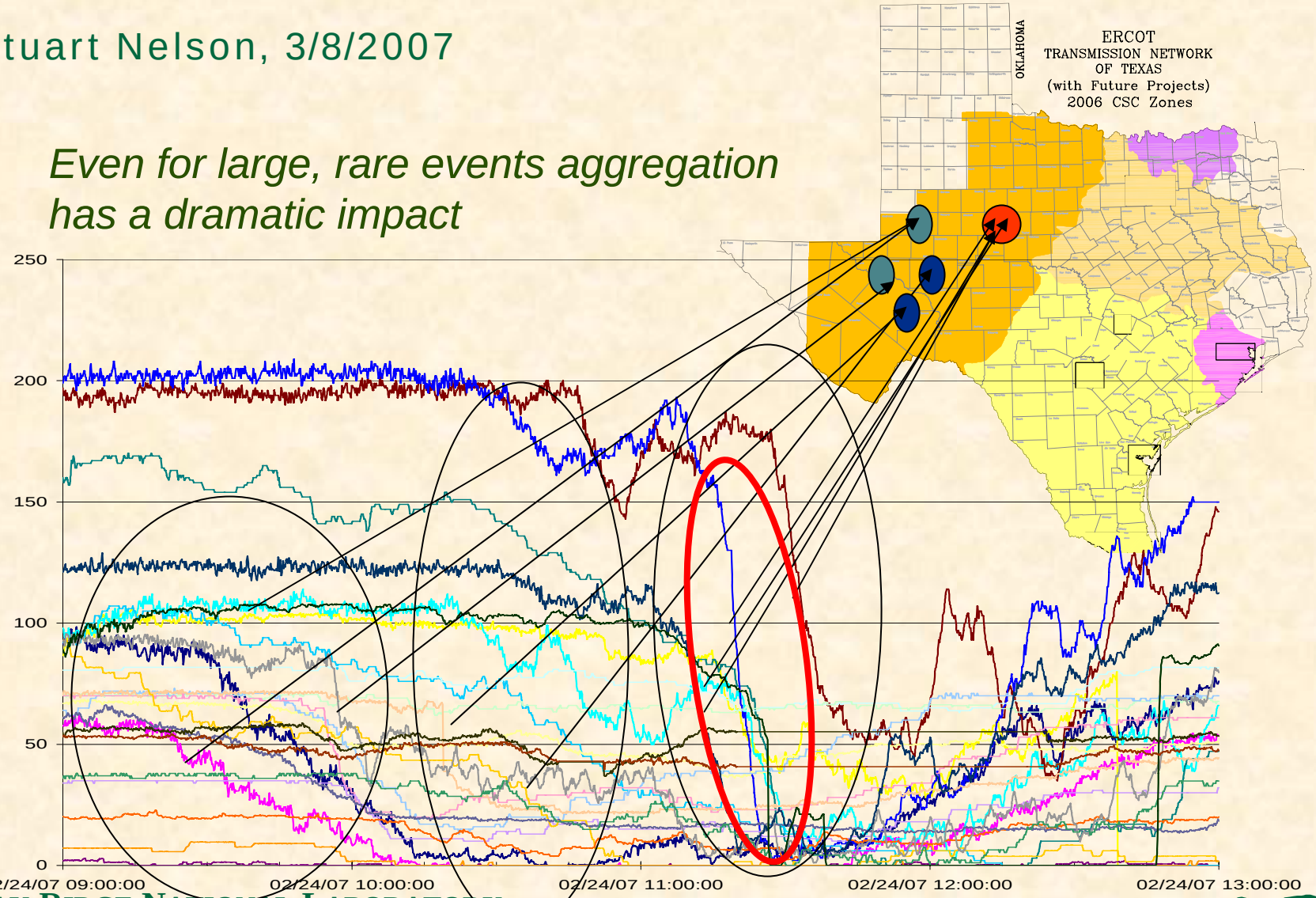
Interestingly, Extreme Wind Events Are Not Typically Contingency Events

- **Extreme wind events are ramping events, not contingency events**
  - **Electrical events are still contingencies (single feeder…)**
  - **Geography prevents all turbines from seeing *wind* events simultaneously and spreads the response**
  - **That is good and bad**
- **Increasing the amount of wind increases the ramp duration, not the ramp speed**
  - **That is good and bad**
- **ERCOT's 2/24/2007 event provides an interesting example**

ERCOT 2/24/2007: 1500 MW Wind Drop

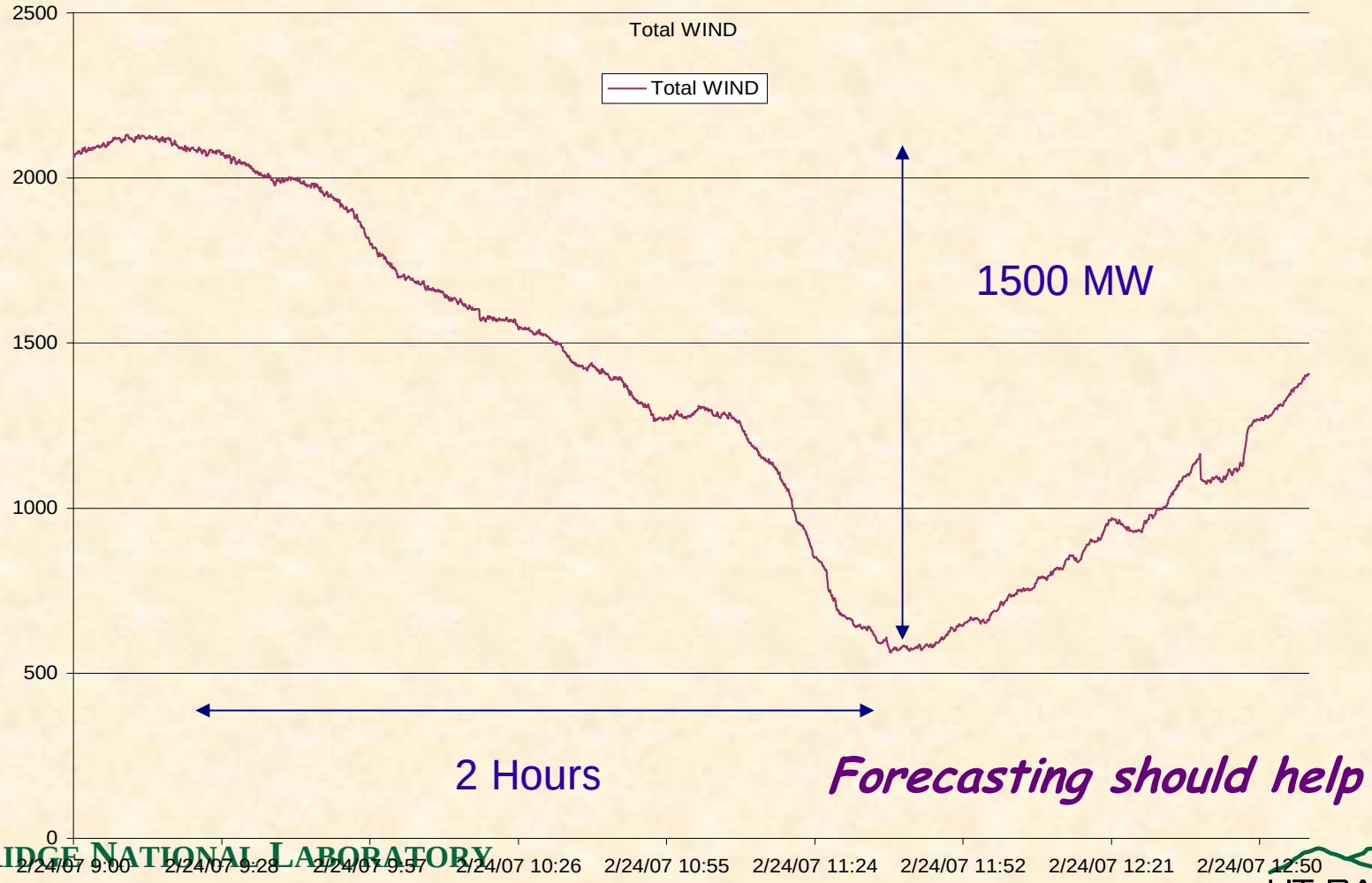
Stuart Nelson, 3/8/2007

Even for large, rare events aggregation has a dramatic impact



~150 MW in ~11 Minutes

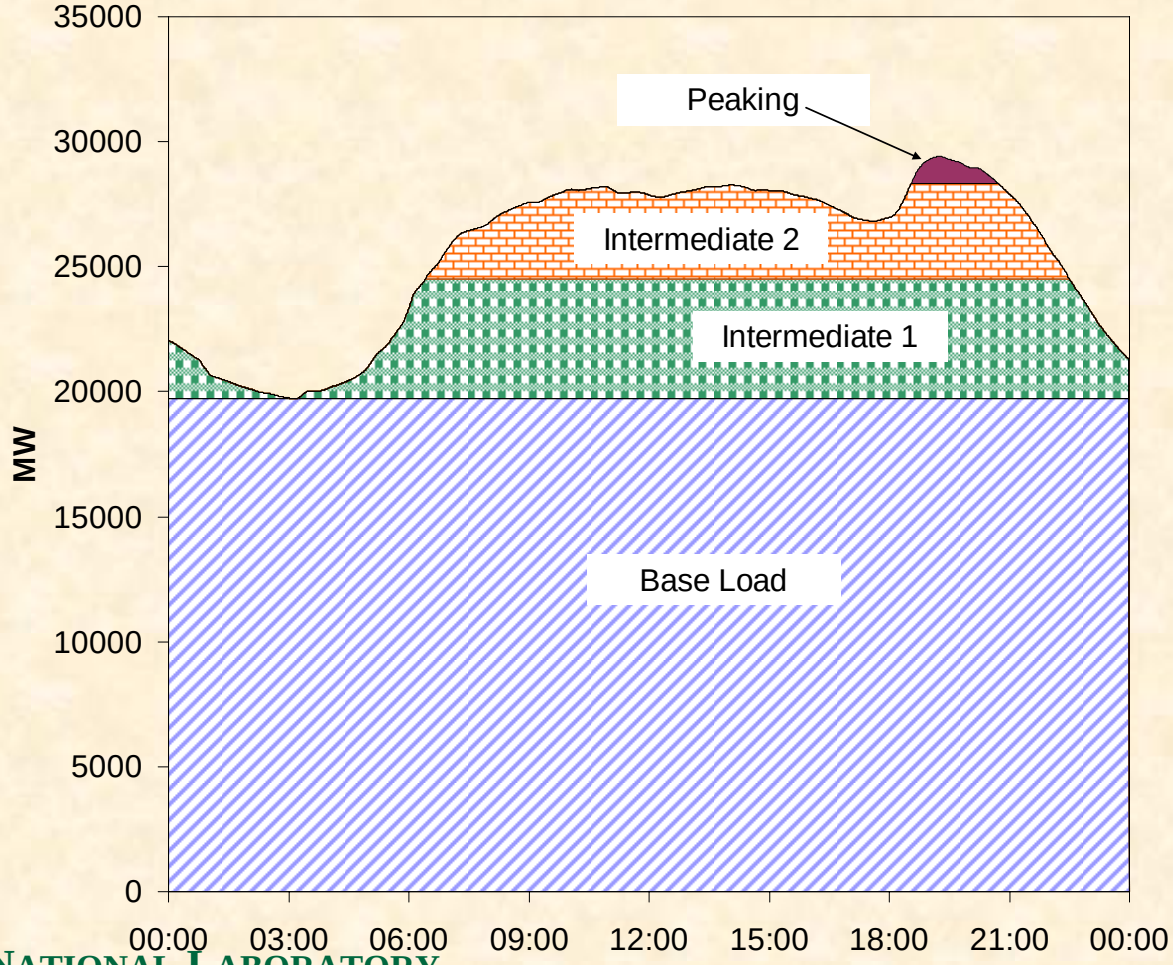
Aggregation Changes Event Characteristics From a Contingency to a Large Ramp / Energy Market



What About Load Following?

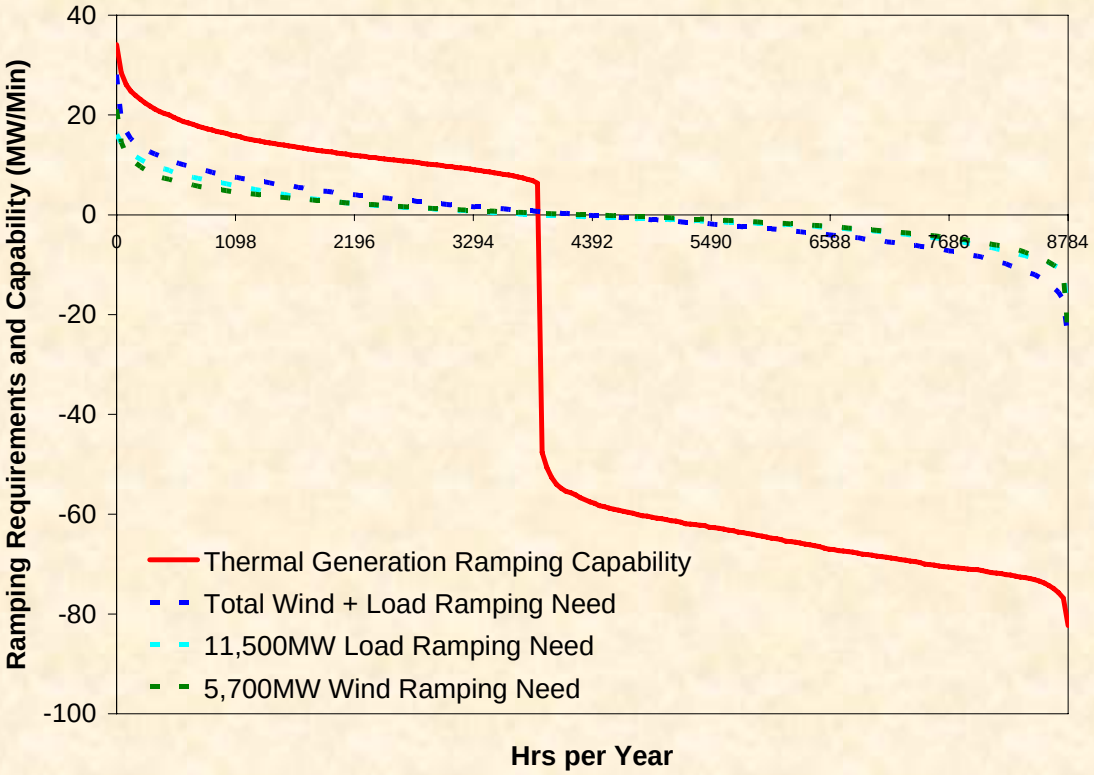
- **Load following is provided by the short-term energy markets or the economic dispatch of the utilities generators**
  - **Regulation comes from dedicated maneuverable capacity where changes are too fast for markets or economic dispatch**
- **Load following is also tied to energy imbalance**
  - **Energy imbalance can be treated with market clearing or with penalties**
  - **Penalties are useful to motivate changes in behavior, they make little sense when applied to physical characteristics**
- **The cost for load following (*or energy imbalance*) depends upon the depth of the short-term generation stack: the amount of generation available to move up and down near the current marginal price**

Participation In Energy Markets Requires Maneuverability For All But Base Load Units



Generation Ramping Capability Typically Exceeds Load and Wind Requirements

- **Minnesota high wind penetration study**
- **Only thermal ramping capability considered (no hydro)**
- **"Tails" can be a problem**



Load Following & Energy Imbalance Conclusions

- **Significant excess ramping capacity appears to exist in the studied systems**
  - **This may explain why market structures do not explicitly value load following**
  - **Modest wind penetration has a modest ramping impact**
- **Excess ramping requirements will impact the short-term energy markets**
  - **Changes in unit commitment will be required**
  - **This can be relatively expensive**
  - **Important for high wind penetration**

Imbalance: Penalties vs Market Clearing

- **Penalties are designed to motivate better behavior from generators that can control output**
  - **Penalties have little influence on the wind**
- **FERC provides partial exemption from imbalance penalties for wind**
- **Some ISOs provide further exemption if wind plants participate in communal forecasting**

Advances in Wind Integration Studies

- **Meso-scale wind modeling provides high resolution wind power**
  - **3 year or longer historic time series**
  - **Time synchronized with utility load**
  - **10 minute or faster resolution**
  - **Geographic resolution matches proposed wind plants**
  - **Typically ~30 MW per synthetic data point**
- **Utility modeling**
  - **Reliability constrained unit commitment and economic dispatch**
  - **Reliability metrics help constant**
  - **Incremental costs determined from modeling with/without wind**

Transmission Concerns

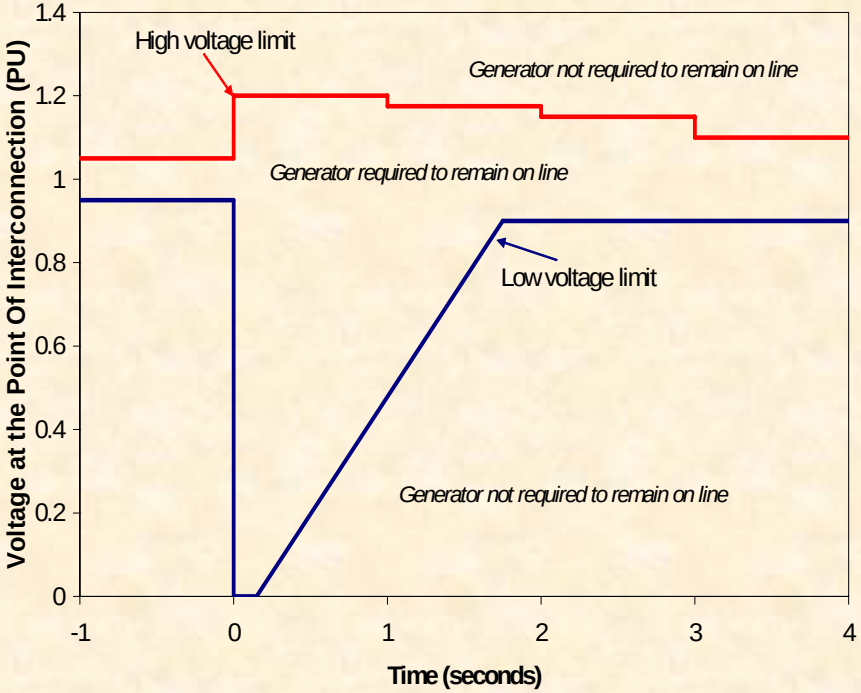
- **Problem: insufficient transmission capacity**
  - **Failure/inability to build for decades throughout the US**
- **Solution: Conditional Firm and Redispatch**
  - **Transmission physically congested only a small % of time**
  - **Allows long-term near-firm contracting whenever physical capacity available**
- **Solution: Build for the resource, not the plant**
  - **ERCOT & California**

Control Capability: Unresolved Issues

- **Wind power excursions can be problematic**
  - **Certain power system conditions (light load)**
  - **Infrequent events ("tails")**
- **Technical advances allow for rapid, accurate control**
  - **Wind plants can be frequency responsive**
  - **Wind plant *could* be operated at part load to provide up and down response**
  - **Good match between wind plant control capability and power system reliability need**
- **Low (or negative) production cost make exercising control expensive**
  - **Wind almost always has the highest opportunity cost**
- **Problem: Exercise control when absolutely necessary for reliability but *only* when absolutely necessary**

Voltage Support

- **FERC Large Generator Interconnection Agreement and Order 661A requires reactive capability from wind generators *when need is shown***
- **Dynamic reactive capability is not a technical challenge for modern turbines**
  - **Showing "need" included in the LGIA because dynamic reactive capability is an expense for wind**

Voltage Ride Through Standard

- **Wind plants originally required to disconnect during voltage events**
  - **Not tenable for large amounts of wind**
- **FERC requires specific low voltage ride through capability for wind generators**
  - **Proposed by wind community to obtain certainty**
  - **Limits low voltage duration to 9 cycles**
- **WECC proposed extending the requirement to all generators and to high voltage**
- **Standard development moved to NERC and started over**