Wind Integration R&D:
Flexibility in resource planning and economics of wind providing regulation

Aidan Tuohy

Sr. Project Engineer

Electric Power Research Institute

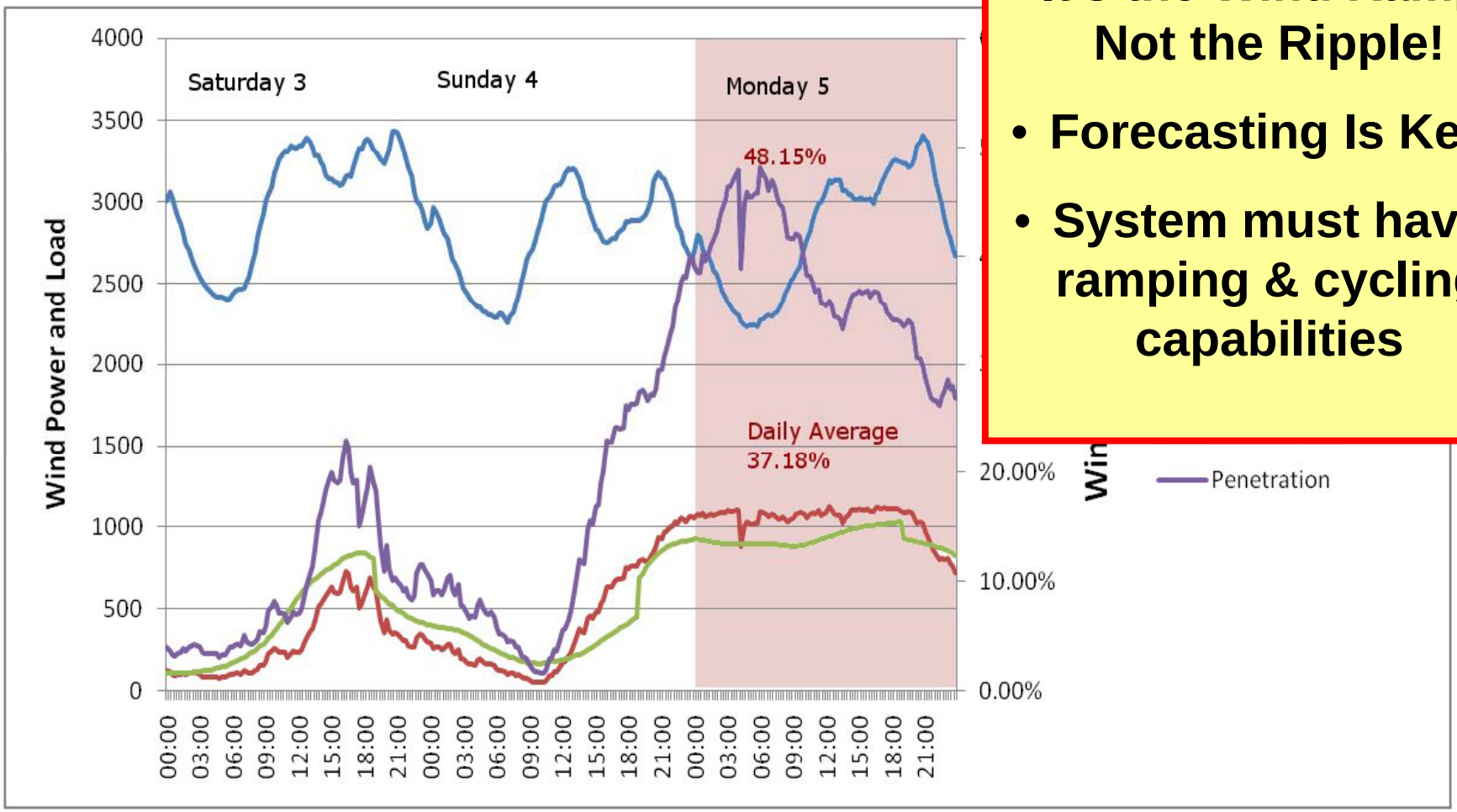
Bulk Renewable Integration R&D Areas

- Variability/Uncertainty
  - Flexibility Needs and Resources
  - Forecasting and market integration
  - Impact of increased cycling on fossil plant
  - Demand response and storage

- Impact of inverter based generation on frequency and voltage stability
  - Model development and validation
  - Provision of reactive support from wind and PV
  - Provision of inertia/primary frequency response, AGC
  - Impact of large amounts of distributed energy resources on bulk system

- Long term adequacy issues
  - Transmission development (incl. HVDC, FACTs, etc)
  - Capacity adequacy

Wind & PV Variability/Uncertainty Increases the Need for System Flexibility

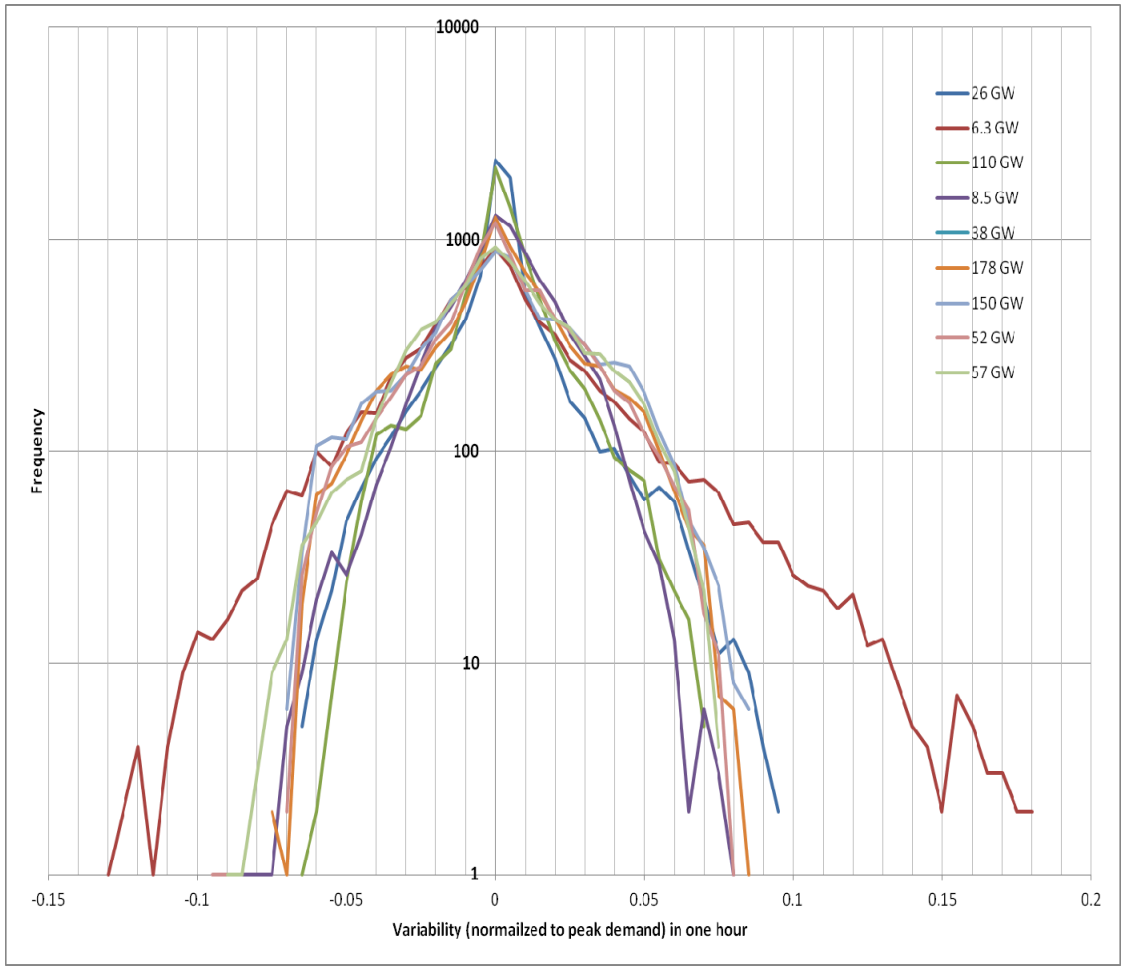


- It's the Wind Ramp, Not the Ripple!
- Forecasting Is Key
- System must have ramping & cycling capabilities

Source: Constructed from EIRGRID online data (www.eirgrid.com).

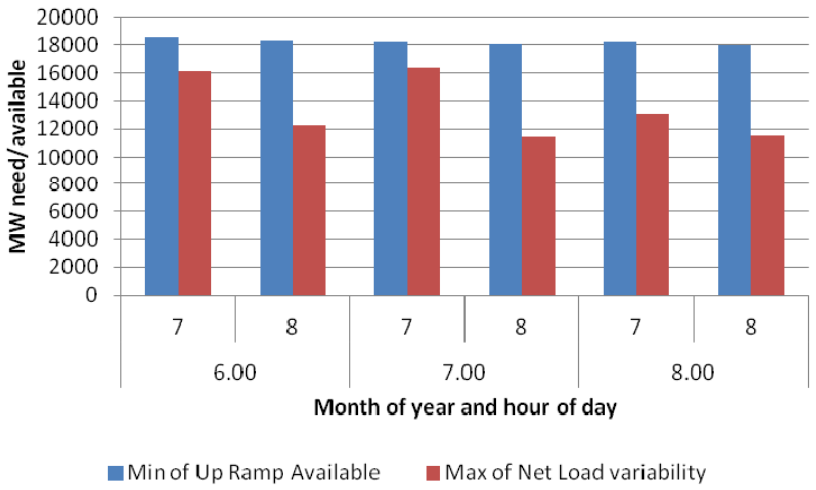
MISO Case Study: Flexibility Needs

- What's important for sources of variability and uncertainty?
  - Magnitude of variability
  - Frequency with which variability occurs
  - Level of uncertainty
  - Correlation geographically
  - Correlation with other tech and load
- Quantify the need for flexibility on different time scales



Most areas within MISO show similar net load variability

MISO: Flexibility Available



- Based on PROMOD runs at MISO, hourly flexibility calculated
- Comparing worst case in particular hour and month
- Always 1500MW + additional flexibility available than needed
- Need to ensure system can access flexibility
  - Markets
  - Transmission

Results are for one future scenario in MISO transmission planning process – preliminary and should be treated as illustrative

Insight from studies thus far…

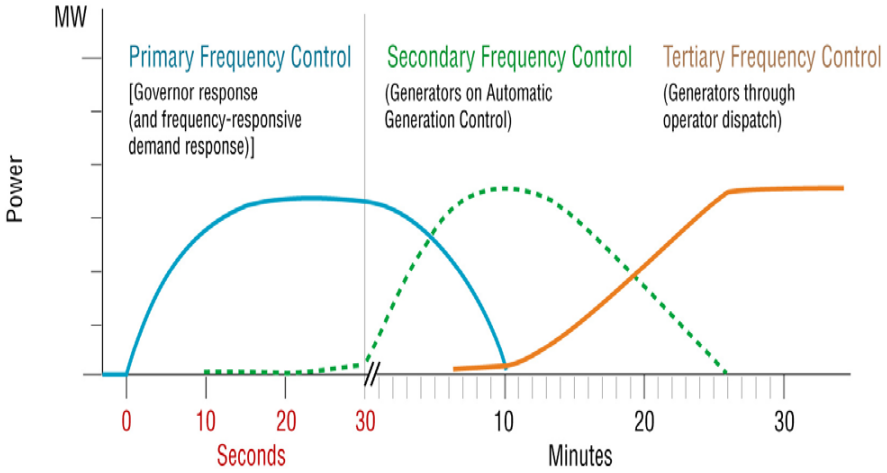
- Quantifying flexibility allows
  - Operational decisions /markets incorporate needs and availability in making decisions
  - Long term planning will consider sufficient flexibility

- Different levels of analytical studies can produce valuable insights
  - Screening may be sufficient for many systems and shows rough approximations
  - Detailed study involves large amount of production cost analysis, but can give detailed results regarding economic performance
  - Security issues also need to be considered – voltage, frequency etc.

- Case study insights:
  - Min generation is important as well as ramping
  - Need to incentivize flexibility resources
  - Certain periods of day and year will be crucial

Active power control from wind

- Wind (and PV in most cases) able to provide of active power control through power electronics
  - Inertia
  - Primary Frequency Response
  - Secondary Frequency Response
- Many manufacturers now provide this, e.g. GE WindINERTIA
- Many ISO/RTOs asking for this – ERCOT, HydroQuebec (though not using it often as of yet)
- NREL/EPRI study looking at different areas of active power control from wind



Graphics Source: LBNL-4142E ***Use of Frequency Response Metrics to Assess the Planning and Operating Requirements for Reliable Integration of Variable Renewable Generation,*** *Prepared for Office of Electric Reliability Federal Energy Regulatory Commission, Dec 2010*

Study on wind providing regulating reserve

- Purpose: Look at steady state impacts of wind providing AGC/regulating reserve

- Production cost based modeling
  - Unit commitment and economic dispatch based on CAISO 2020 33% Integration Study
  - Plexos - Zonal model of entire Western Interconnect in 2020

- Examine production cost, generation, price impacts of wind bidding into regulating reserve market for 2 months of year

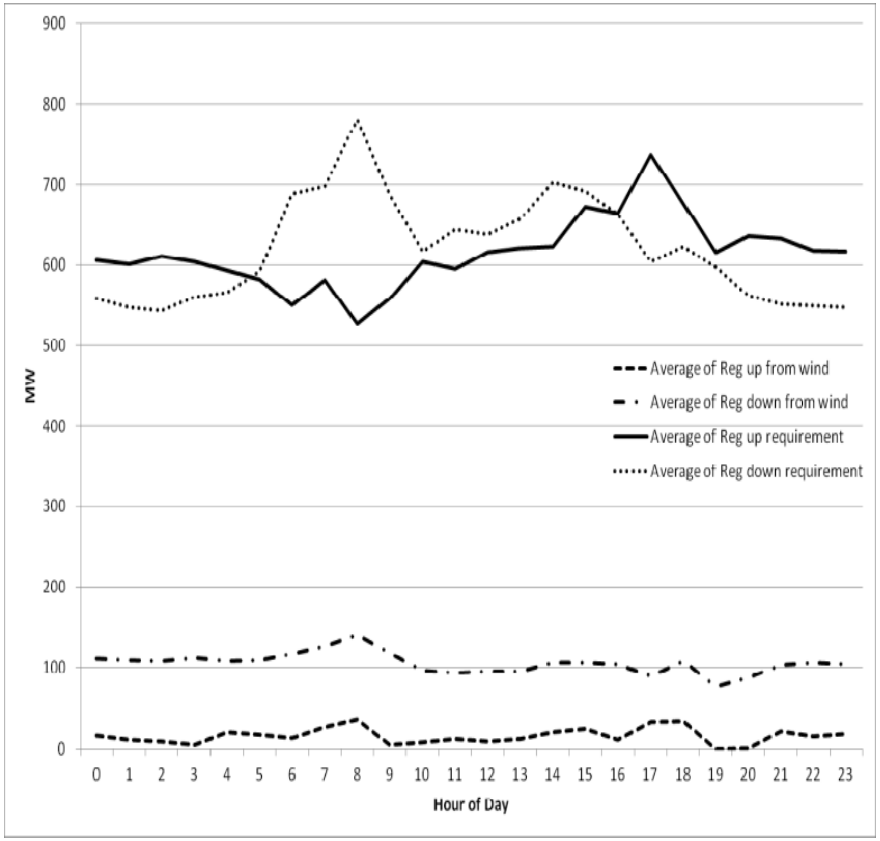
Impacts of wind providing regulating reserve

System Costs Impact

Case	WI Costs ($)	CA costs	CA Start Costs	Net Import to CA (GWh)
No Reg from wind	$5,610m	$1,550m	$27.9m	7,359
Wind Provides 20% of reg up and down	$5,607m	$1,531m	$26.3m	7,626
Change	-$3.1m	-$19.5m	$1.6m	267
Change (% of base)	-0.2%	-1.3%	-5.7%	3.6%

Increase in wind revenue of $1/MWh due to provision of regulation

Provision of regulating reserve



Conclusions

- Wind provides regulation response which benefits system production costs and could increase profits
  - Not considering PTC here
  - No consideration of forecast uncertainty
- FERC 755 (pay for performance) → power electronics would mean very accurate response from wind
- Sensitive to limit of how much wind can provide
  - Reg up and down separate in CAISO, joint elsewhere
  - Much of benefits are for very few hours of year
  - Down regulation less valuable but more common

Together…Shaping the Future of Electricity