PacifiCorp

Modeling Wind Energy Integration Costs

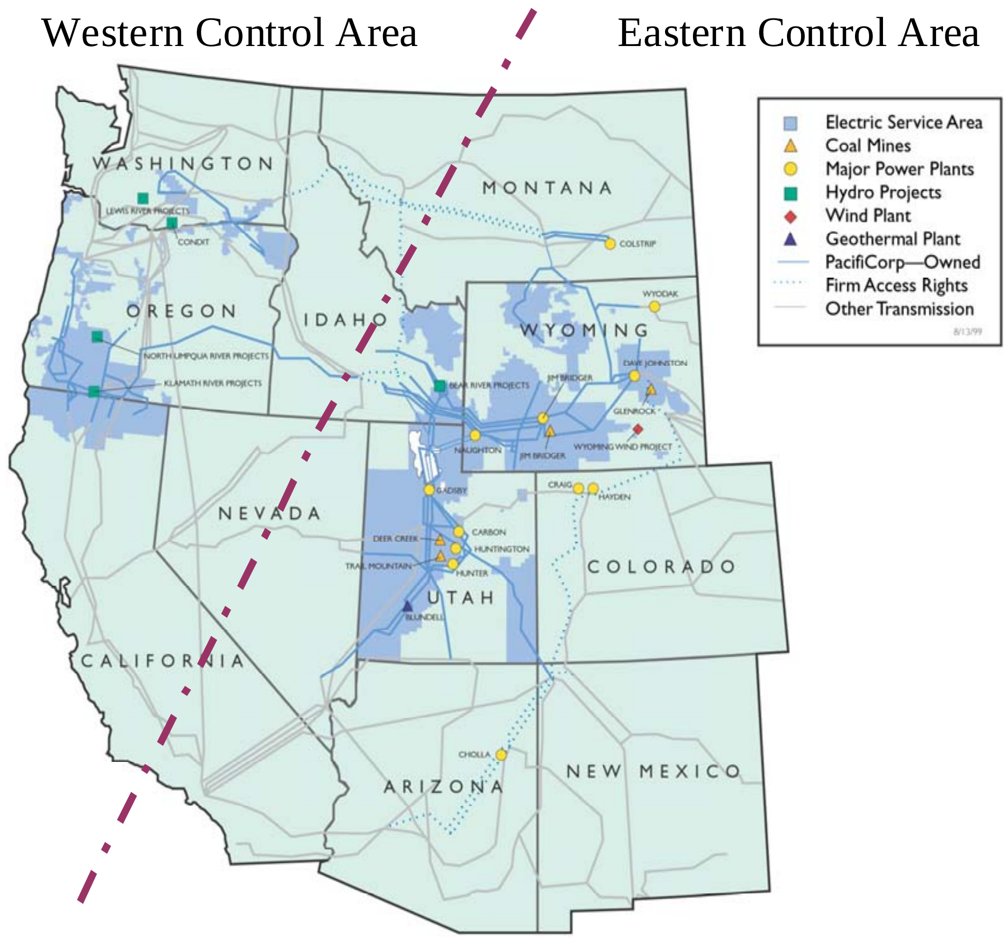
UWIG Technical Wind Workshop
Seattle, WA

Tom Coatney 23 Oct 2003

PacifiCorp's Power System

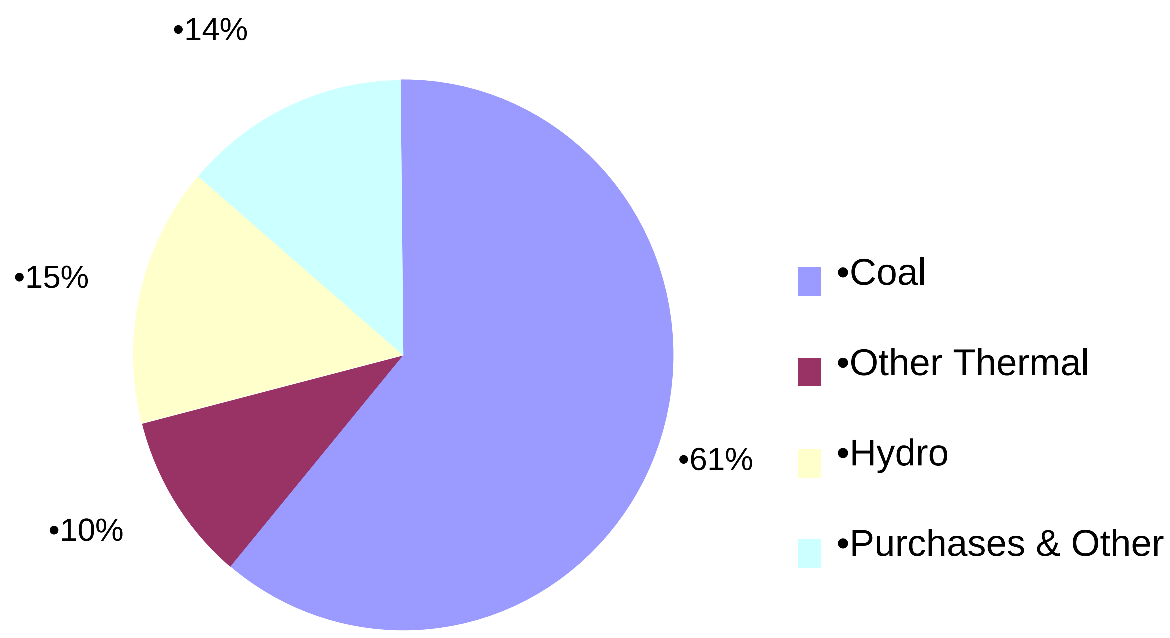
PacifiCorp's power system is divided into two separate control areas.

Transmission interconnection between the two control areas allows for resource sharing.



Current Supply Portfolio

•10,000 MW Summer Capacity



Wind As A Portfolio Element

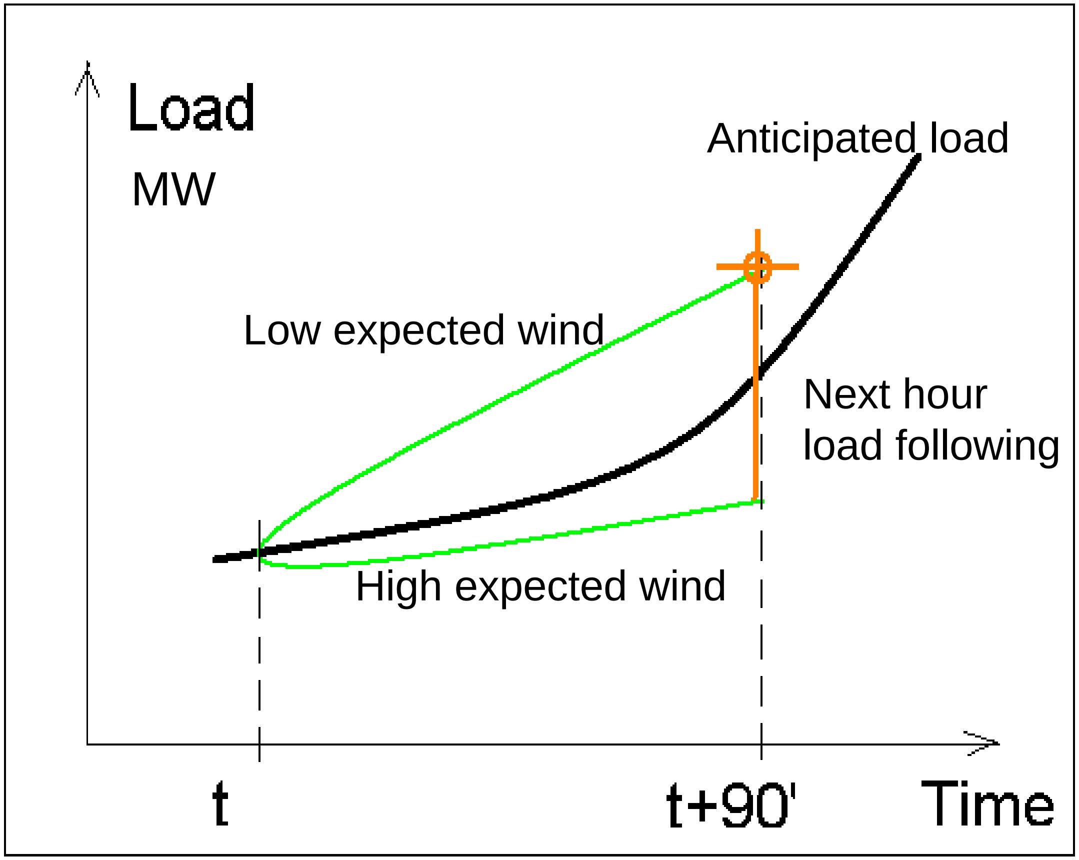
- Why wind is good…
  - Fuel diversity and low variable cost.
  - Clear environmental advantages, financial benefits under cap and trade programs for SOx and NOx.
  - Economically neutral with production and green tax credits (when subsidized).
  - Reduces overall cost and risk of portfolio.
- Why wind is uncertain...
  - Unknown availability of advantaged sites.
  - Transmission access to remote locations can be difficult and expensive.
  - Transmission and reserves rules are in flux.
  - Output variability.
  - Difficult modeling and optimization of integration.

Defining Integration Costs

- » Incremental Reserve Requirements.
  - The need for additional reserves to maintain system reliability and security due to the variable output of wind generation.
- » Imbalance Costs.
  - Additional operating costs incurred due to the variable output of wind generation.
    - ⇒Costs may accrue from:
      - – Additional unit startups.
      - – Incremental market interactions.
      - – Operating thermal and hydro units off optimal levels.
      - – Forecast errors.

Incremental Reserve Requirements

PacifiCorp's analysis assumed that the relevant time scale is minutes to hours, implying need for additional load following reserves.

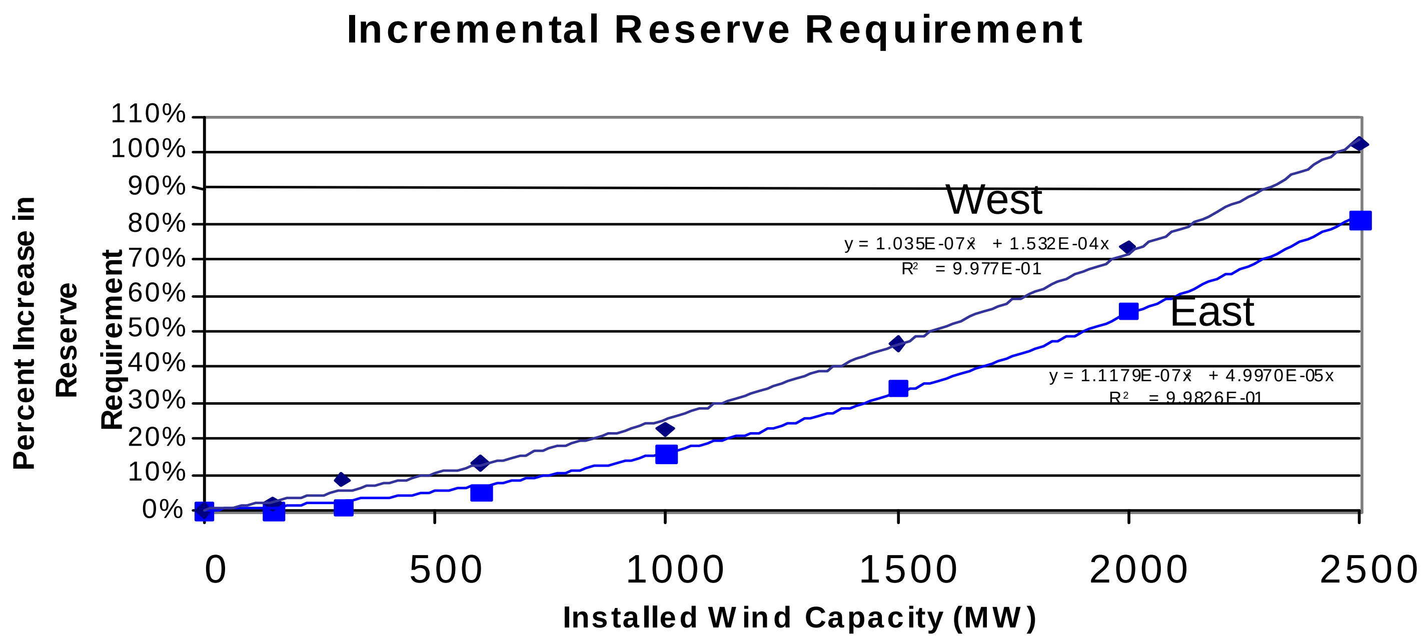


Incremental Reserve Methodology

- » Used simulated loads and pseudo-historical wind generation.
- » Computed the fractional increase in standard deviation of hourly load net of wind generation.
- » The fractional increase was applied to currently held load following reserve levels.
  - Load following reserve levels are based on operational experience.
  - If load volatility as measured by the standard deviation increased 10%, PacifiCorp assumed 10% more load following reserves would be needed.

Incremental Reserve Calculation Results

- Virtually no incremental reserves needed at low penetration levels.
- Need for incremental reserves rises rapidly at significant penetration levels.



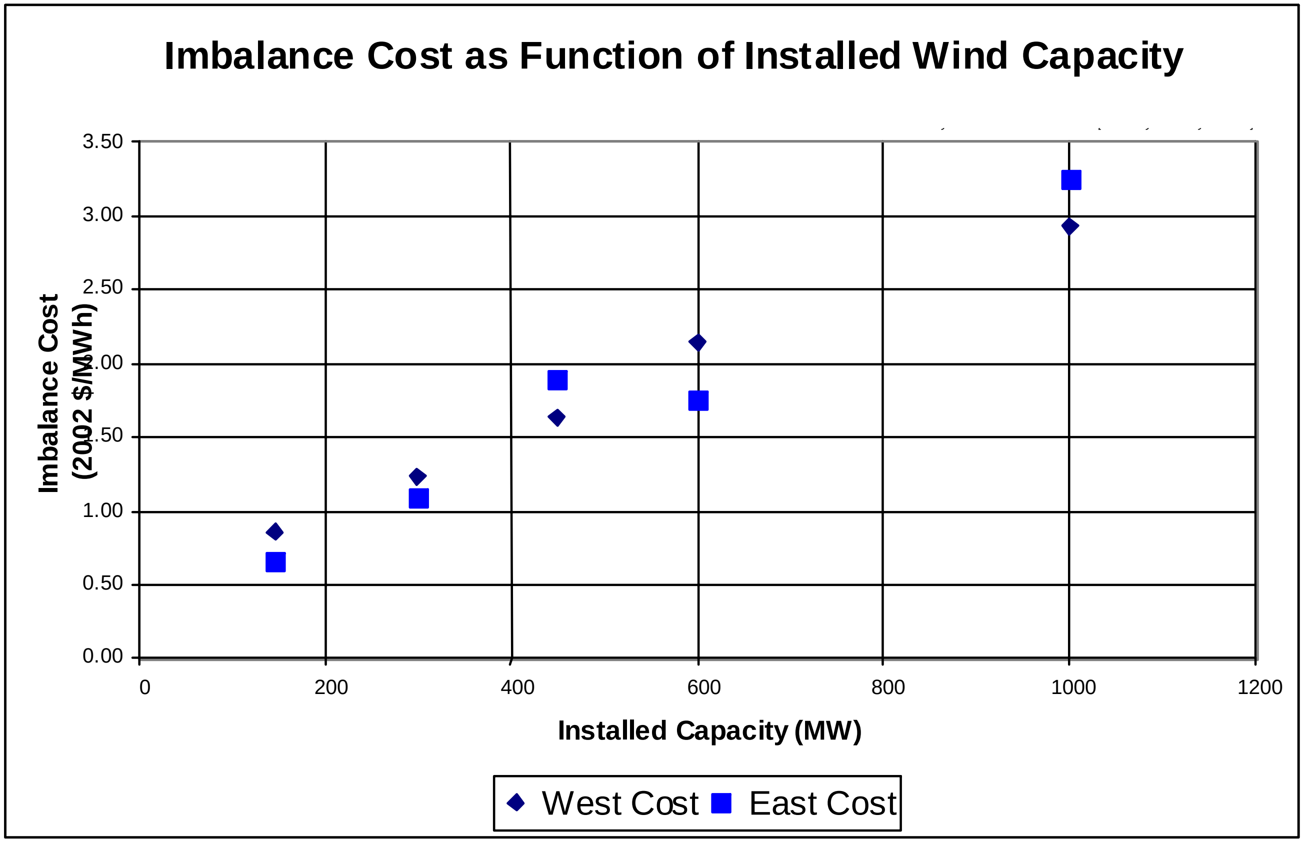
Imbalance Costs

» Henwood's PROSYM hourly dispatch model was used to assess operating costs.

- Study run to meet loads with access to wholesale power markets, including hour-by-hour wind generation from a pseudo-historical data set.
- Study was run a second time with wind generation replaced by an equivalent amount of energy supplied at a constant rate over the year.
- Difference in operating costs attributed to variability of wind output and expressed on a cost per megawatt hour basis.

Imbalance Cost Results

Imbalance costs appear to increase linearly with installed capacity over the range examined.



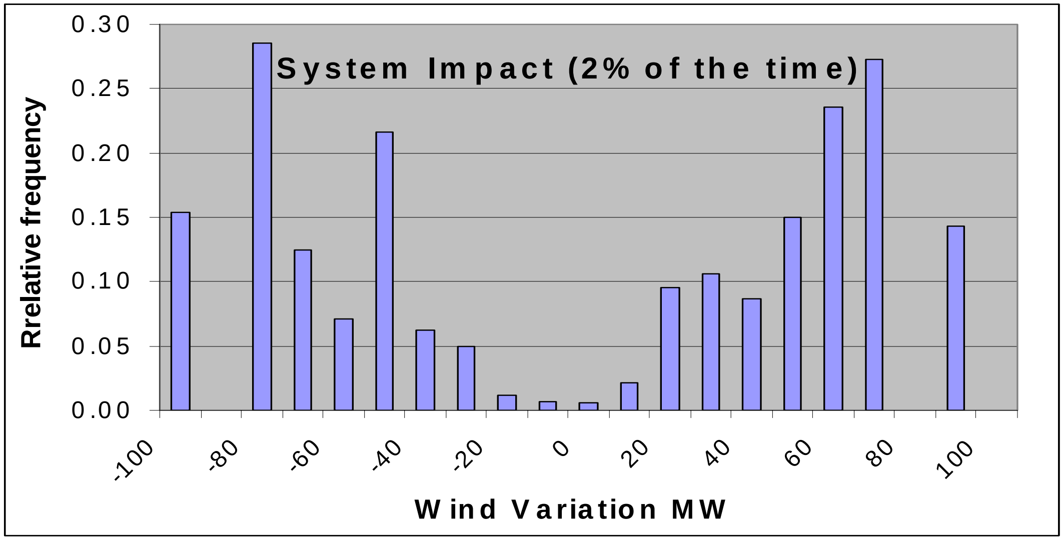
Real time wind integration analysis

- Study conducted from Dec 02 to Feb 03.
- Output: West side- 150MW, and East side resources - 170MW. (Data from Control Area Operations).
- Operators did not use wind forecasting.

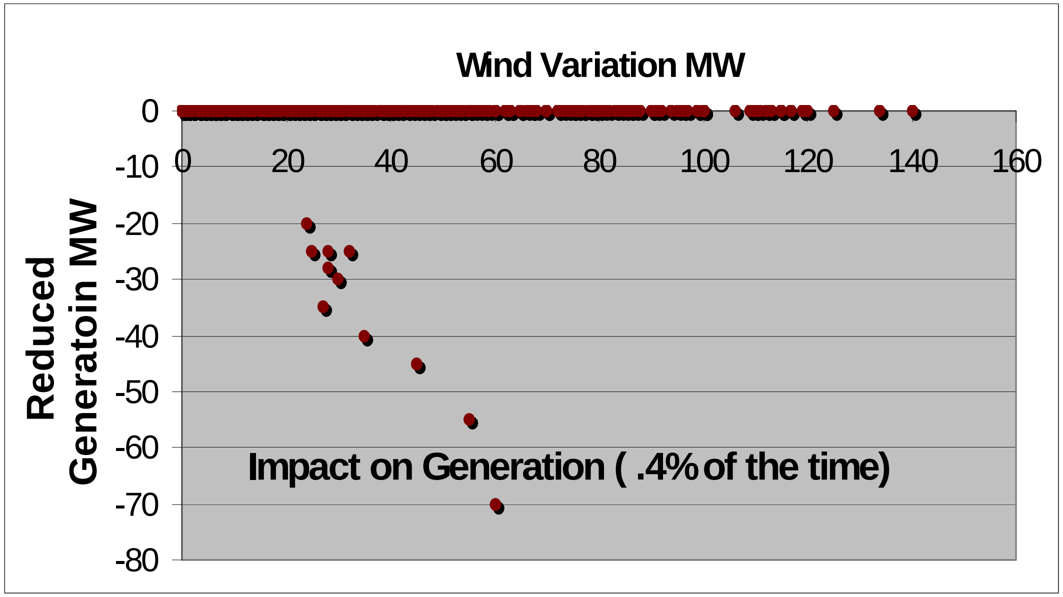
- Operators notice an impact mostly when wind variation is outside the +/- 40MW Control Performance Standard (CPS1) band.
- Current level of wind penetration has only marginal impact on load following.
- Only anecdotal evidence to support forecasting at this level of wind energy penetration.

Real time wind integration analysis

The need to change dispatch plans was considered to be a system impact.



Low impact on generation is in line with theoretical expectations.



PacifiCorp Integrated Resource Plan

- » Issued on January 24, 2003
- » Secured all state PUC acknowledgements of plan - will serve as important roadmap to guide resource investments.
- » Substantial amount of renewables – 1,400 MW. Well received by state energy offices and environmental groups for analysis of integration costs, consideration of environmental risk values, and diligent effort to characterize renewables costs
- » Assumptions / Caveats on Wind Integration Study:
  - PROSYM accurately reflects balancing costs.
  - Operating reserve changes proportional to hourly load volatility net of wind.
  - Cost of reserves constant relative to market prices (i.e. no volatility assumed.)
  - Transmission is adequate to fully integrate wind resources into system.
  - Intra-hour variability is not significant.
  - RTO could have a significant impact – direction unknown.

Conclusions

- Integration costs are real, increase with greater penetration levels, and may be significant at high penetration levels.
- Integration costs can be estimated with available models and techniques.
- Dispatch models can be used to estimate costs, and improvements are further refining the estimates.
- Future developments;
  - Accounting for liquidity risk.
  - Accounting for price volatility.
  - Model optimal wind/peaking resources interaction.