Wind Integration 101

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The Nature of Wind Energy

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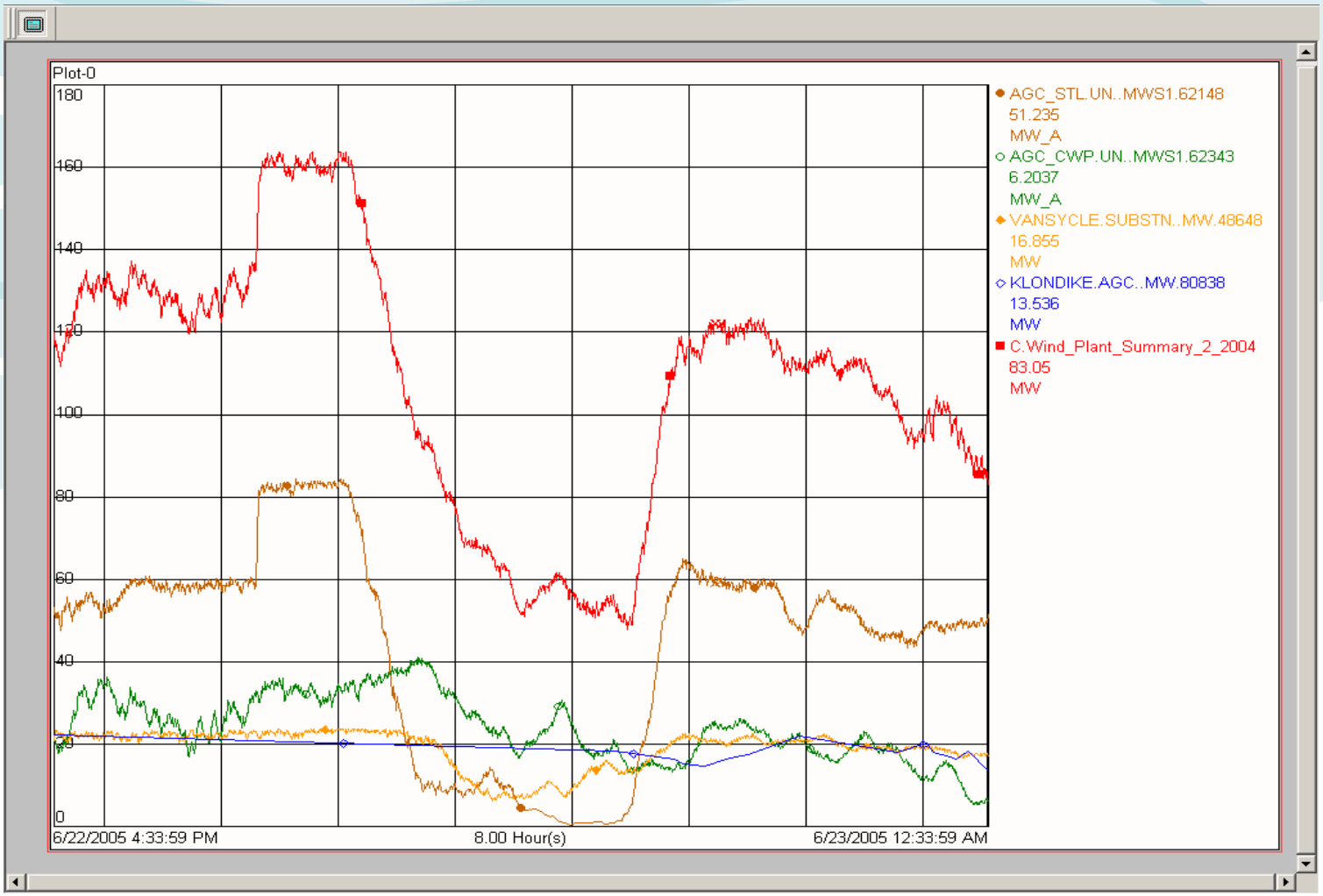
Wind energy is an environmentally friendly, yet intermittent and variable source of electricity generation.

In the Northwest, wind projects average about 30 to 36% capacity factor, meaning their average generation is approximately 30 to 36% of their nameplate capacity.

The output of individual wind projects can be highly variable over short time horizons – even minute-to-minute fluctuations can be over 25% of installed capacity.

Unlike dispatchable generation, only limited control of wind project output is possible, including the ability to control ramp-up rates and maximum levels of generation.

Variable Wind Project Output



The Portfolio Effect

It is important to remember, however, that wind output is blended into the entire utility portfolio of loads and resources, which already contains large sources of variability – elevators, light rail trains, industrial processes, freeway lights, and variations in other generating resources as well.

This blending of wind output into the broader portfolio helps dampen the impact of individual wind project variability on the total system.

Broader geographical diversification of wind plants can also help smoothen the impacts of wind variability on the system as a whole.

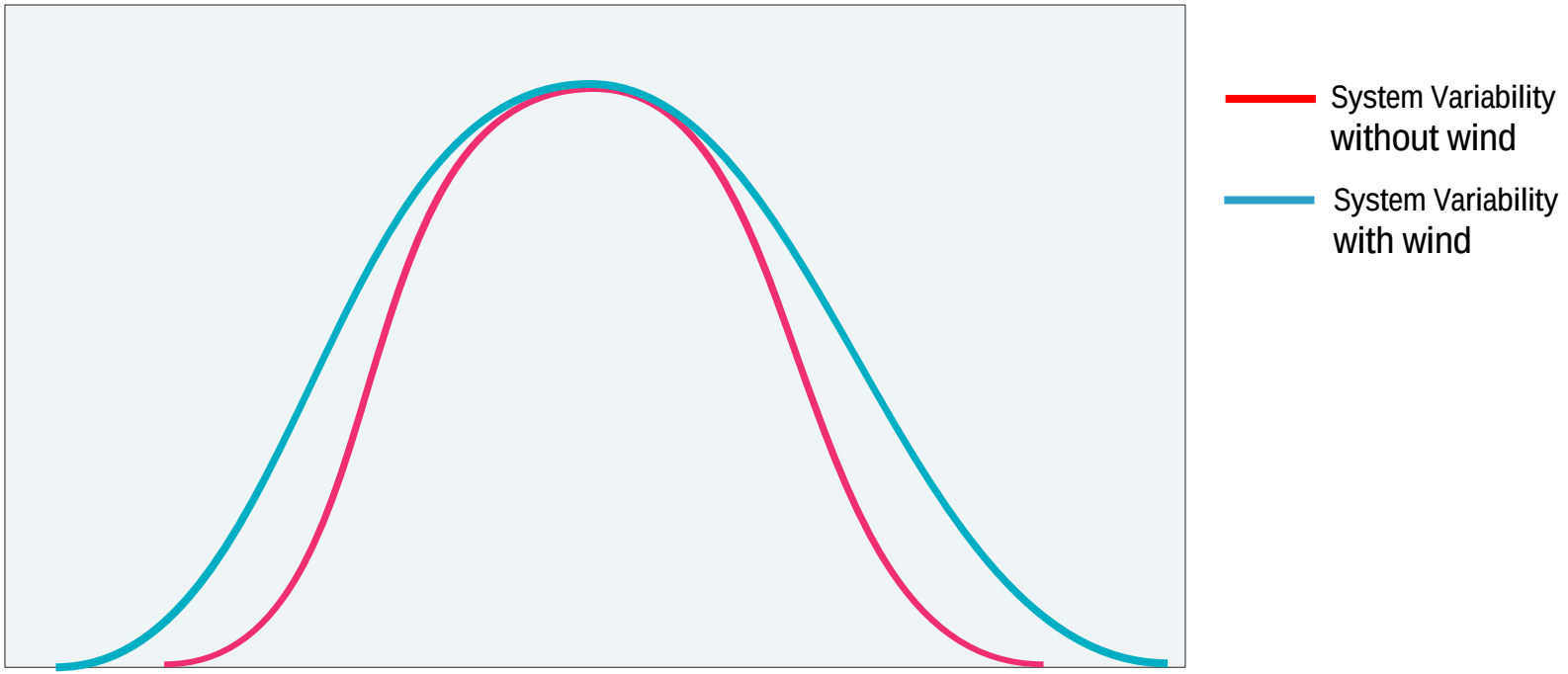
Managing the “Tails”

Much of the time, even with relatively large amounts of wind in a utility portfolio, changes in wind output and changes in other system variables tend to offset each other, so the incremental variability created by wind is not very large.

However, like most phenomena, there are “tail events,” involving large wind ramping events during which wind generation can increase or decrease dramatically over relatively short time periods.

As a result, it is widely acknowledged that wind generation increases the variability of system operations at the 2 to 3 standard deviation level.

Impacts on Total System Variability



In other words, wind energy can increase the total variability of system operations. These impacts are real and can affect reliability and operating costs. They can also increase over time with growing wind penetration. Quantifying and learning how to best manage these impacts will be a major thrust of the Work Plan.

“Wind Integration”

The term “Wind Integration” means different things to different people involved in utility operations and planning.

Transmission Engineering Perspective

Transmission Engineering

To a transmission engineer, wind integration is primarily about building sub-stations and feeder lines to physically interconnect the output of wind projects into the high voltage transmission system, and about upgrades and expansions to the bulk long-distance transmission system needed to transfer wind energy output to loads.

At the point of physical interconnection, there are operating impacts measured over very small time scales, usually fractions of a second, related to voltage and system stability.

In recent years, wind turbine technology has made considerable strides in addressing these very short-term impacts. These include the ability to “ride though” drops in voltage without tripping off line and the ability to provide reactive power support to the system.

Interconnection Infrastructure

High Voltage Transmission lines in Southern Washington

Feeder Lines for PPM's Big Horn Project

Spring Creek Switchyard

Control Area Operations Perspective

Control Area Operations

To a Control Area Operator, wind integration is primarily about maintaining the balance of loads and resources, net of any additional system variability created by wind generation.

Control Area Operations

Control Area Operators use the flexibility of generating resources such as hydroelectric dams and gas plants to ramp up and down to manage changes in system load/resource balance.

By industry convention, there are different names for this type of ramping action, defined by time-scale.

“Regulation” or “Frequency Regulation” is the process of following minute-to-minute changes in system balance.

Regulation is usually provided by power plants on Automatic Generation Control (AGC), meaning plants that respond electronically to changes in the frequency of the Control Area.

Control Area Operations

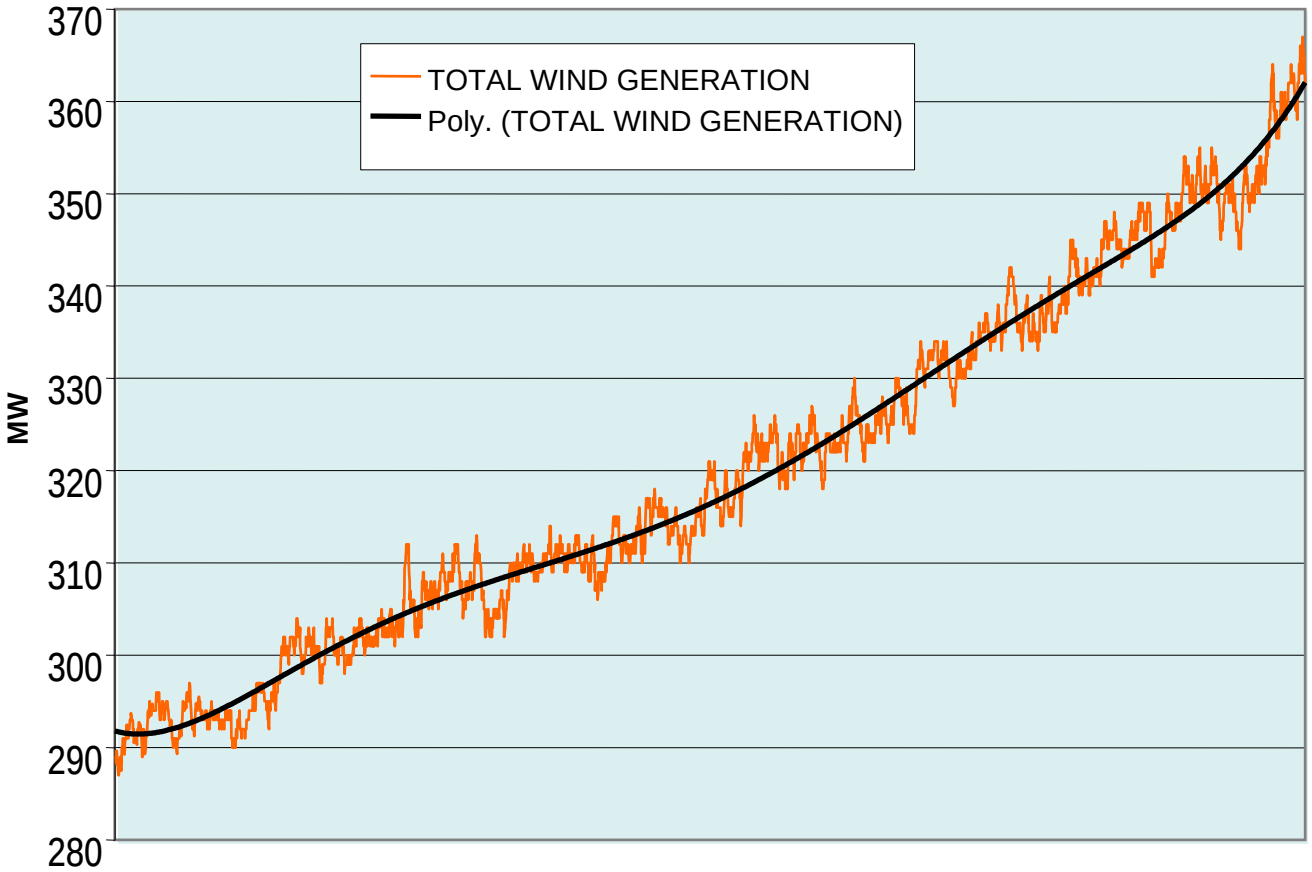
In the United States, our utility systems are operated at 60Hz, or 60 cycles per second. When aggregate generation exceeds aggregate load, frequency increases above 60Hz, and units on AGC will back down to restore frequency to 60Hz. Likewise, if generation is less than load, the system will “slow down” to a level below 60Hz, and units on AGC will increase their output to restore system balance.

Regulation maintains this balance over very short time spans.

“Load Following” is a term that is typically applied to the process of balancing loads and resources over longer time periods, beyond the moment-to-moment changes associated with regulation.

Regulation and Load Following

Load following can be thought of as the trend in system load/resource balance, and regulation as the noise around that trend.



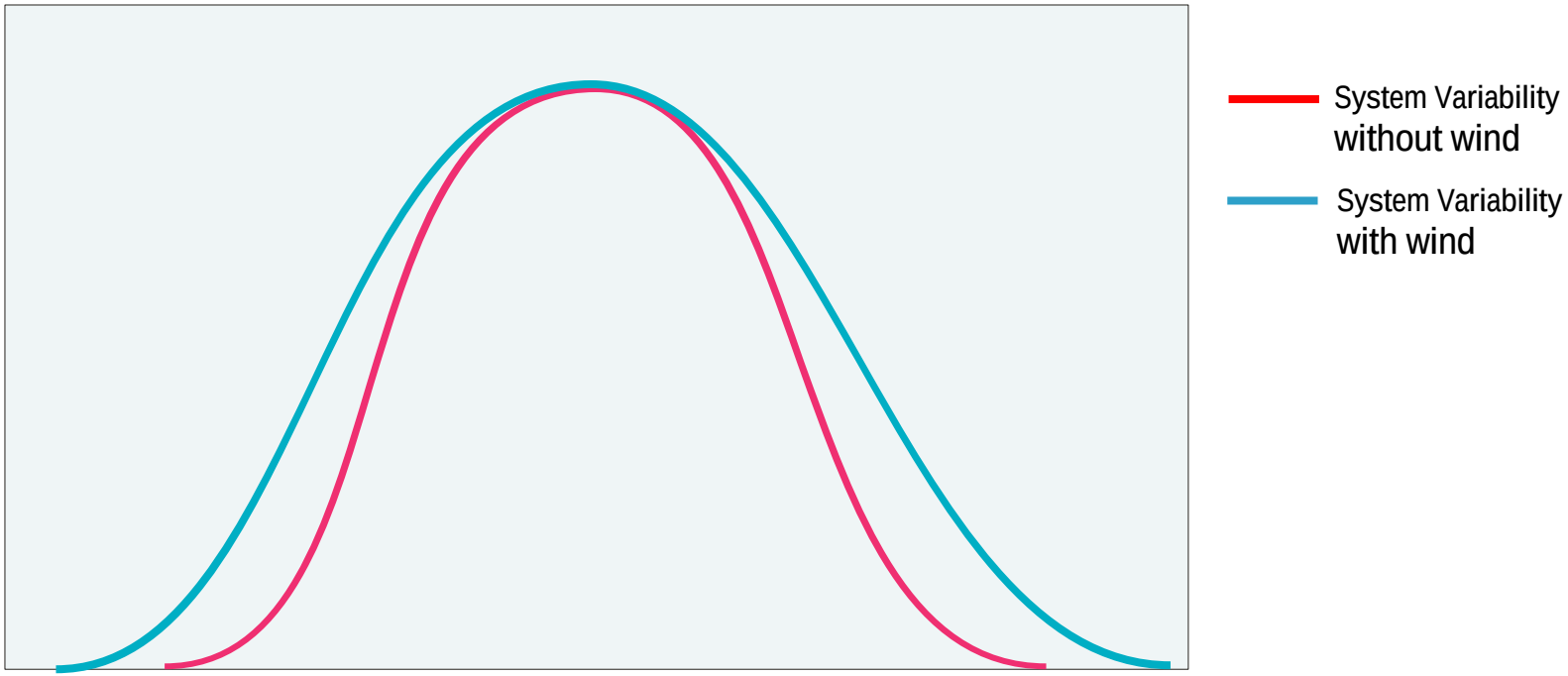
Control Area Operations

The distinctions between regulation and load following are somewhat arbitrary. They have been known to create confusion even amongst experienced operators.

Together, regulation and load following can be referred to as “balancing capacity” or that portion of the generation fleet that must be set aside to maintain load and resource balance within the scheduling hour.

The John Day Dam is a major source of balancing capacity for the BPA System

Balancing Capacity Requirements



Since under certain conditions, wind generation increases the total variability of the system, Control Area Operators will have to carry more balancing capacity to maintain reliability. Here is where the costs of wind integration come into play for Control Area operations.

Power System Dispatcher Perspective

Power System Dispatch

To a power system dispatcher, who constantly forecasts load and calculates a preferred system dispatch to meet that load, wind variability adds uncertainty about how much generation will be available to serve load during future time periods, from the next hour to the next day and beyond.

For example, during the first 30 minutes of every hour, power system dispatchers look forward to the next operating hour and ask several questions: What is my expected load? How much generating capability do I have available to meet that load? Which combination of power plants or market purchases should I use to meet my obligations?

Hourly Scheduling Uncertainty

Prior to each scheduling hour, the dispatcher must look to a forecast of the amount of wind generation that will be available to serve load. The system dispatcher must decide how confident he is in the wind forecast. If relatively confident, he will rely on the forecast and schedule accordingly.

However, if there is a wide range of uncertainty around the forecast, he may have to make additional market purchases or bring additional generation on line to meet expected load for the next hour.

Facing an uncertain forecast, the dispatcher may then have to schedule the wind using a rule of thumb or set the schedule of anticipated wind output to zero.

Imbalance Costs

Once these operating and scheduling decisions are made, the dispatcher faces imbalance energy costs if the wind does not generate according to its schedule. This imbalance energy must be purchased from (or sold to) the control area operator at market-based prices and supplied (or absorbed) using the same generating capability that is set aside for control area balancing.

Either the load serving entity or the wind generator will be exposed to these imbalance energy costs, but it likely that loads will pay for them in one way or another.

However, anecdotal evidence from wind generators in the Northwest has indicated that imbalance costs have not been very high.

Power System Dispatch
Day-Ahead Impacts

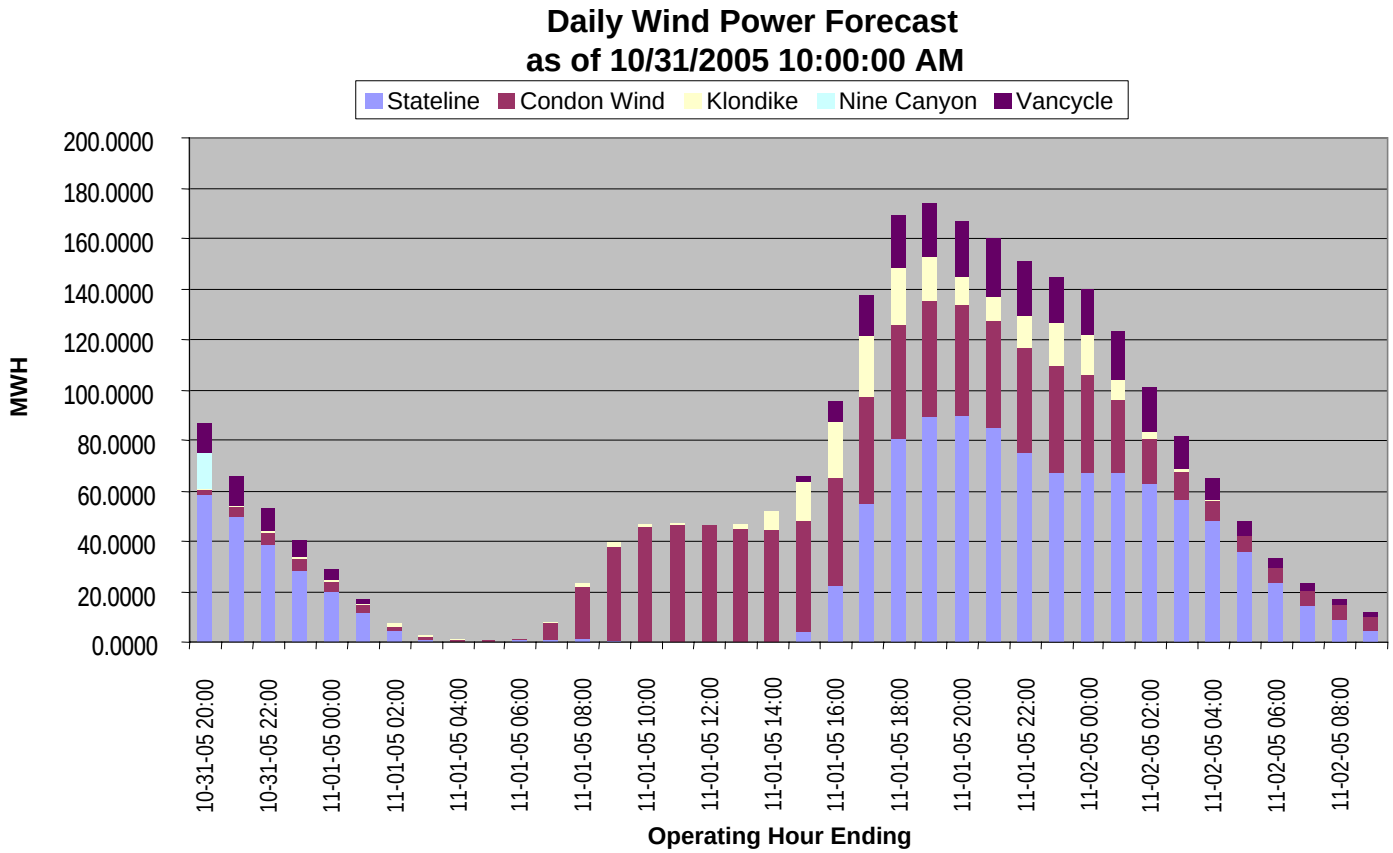
In the Day-Ahead market, the power dispatcher faces similar uncertainty in choosing which power projects to operate during the next day. The problem can be amplified, because the uncertainty around wind in the day-ahead time frame is larger than that on an hour-to-hour basis.

Dispatchers may have to be overly conservative in their buying or selling decisions, which can increase direct or opportunity costs.

The Work Plan will pool the collective knowledge and expertise of our power system operators to develop strategies to manage this variability in a cost-effective fashion.

Wind Forecasting

Wind forecasting is a rapidly-developing science and is being used in the Northwest to assist with the integration of windpower. An integrated regional wind forecasting network may provide significantly improved forecasts.

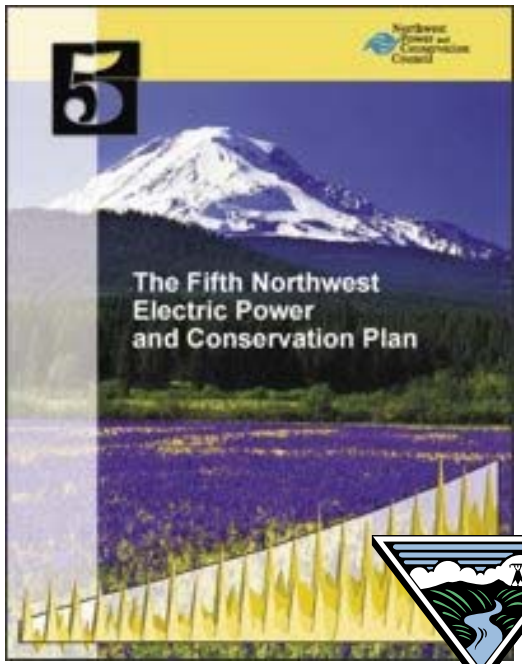


System Flexibility

"System Flexibility" refers to the ability of the power system to provide regulation, load-following and energy storage services. Hydropower is often viewed as the ideal resource for these purposes because of its rapid ramping and energy storage capability. Combined and simple-cycle combustion turbines, and fossil steam units designed for rapid changes in loading provide regulation and load following in thermally-dominated power systems. Other resources that may be able to provide these services if augmentation of regional system flexibility is needed in the future include combined-cycle plants equipped with duct firing, pumped storage hydro, advanced energy storage technologies such as regenerative fuel cells, and possibly, demand response.

System Planning Perspective

System Planning

To a power system planner, wind integration raises questions about how much energy will be provided to the system during different seasons of the year and during heavy and light load hours. Long-term planners must also grapple with fundamental questions about the capacity value of wind for system reliability and planning reserve purposes, and whether wind output should be treated more like negative load than an actual capacity resource.

Ultimately, wind energy, with its unique operating characteristics, must be integrated into all phases of system operation, from the sub-second level of voltage stability, to within-hour control area operations, to hour ahead and day-ahead unit commitment and finally to the process of long-term system planning.