

# Integration of Wind and Hydropower Systems: Simplified Modeling

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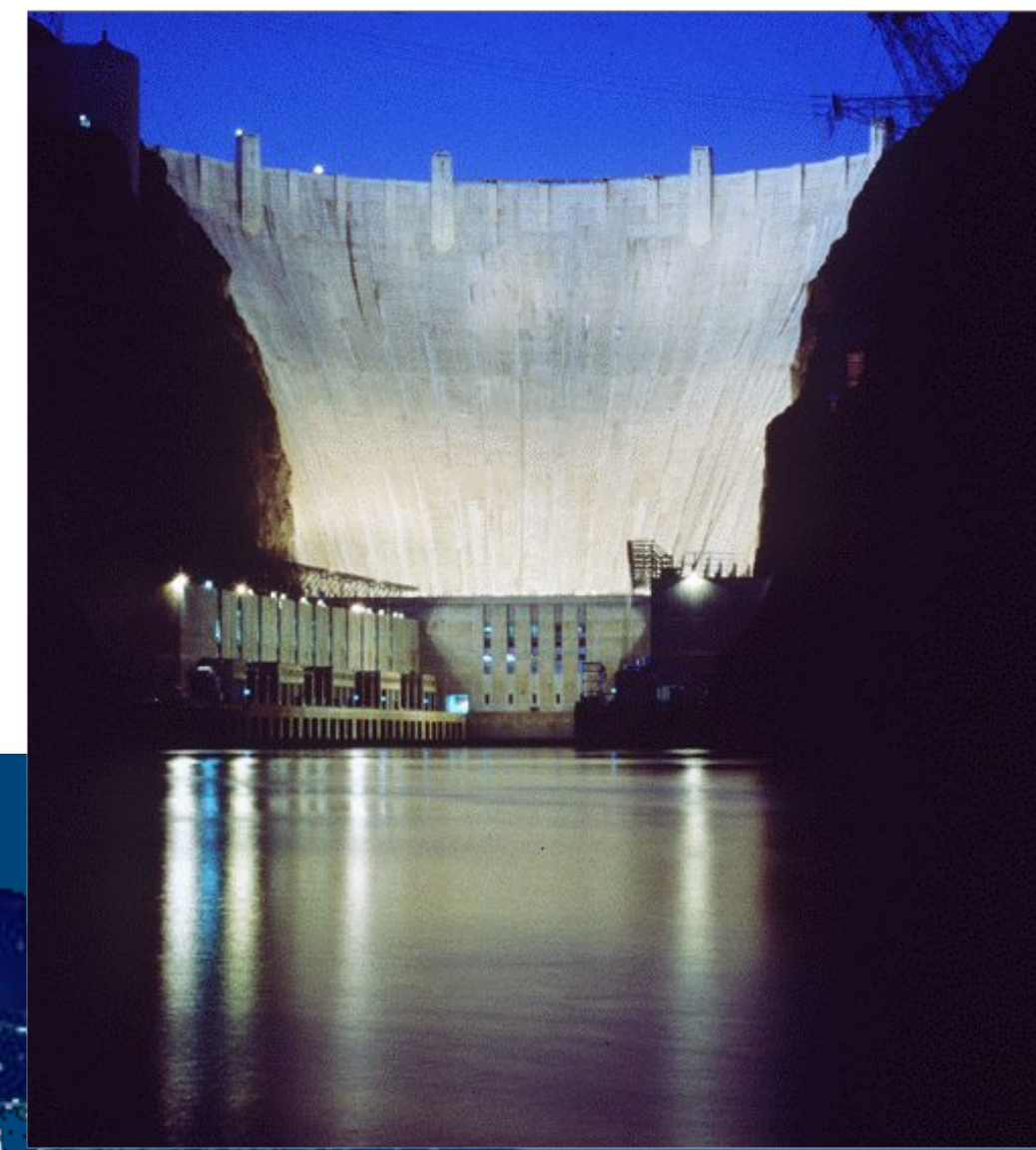


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Sustainable Energy Solutions

## GOALS

- Characterize electrical control areas in terms of their generation, transmission, and loads to enable an estimate of the ancillary service costs required to integrate wind power.
- Devise a method to characterize the hydropower resources and their constraints in an electrical control area, and their ability to provide these ancillary services.



## STUDY REQUIREMENTS

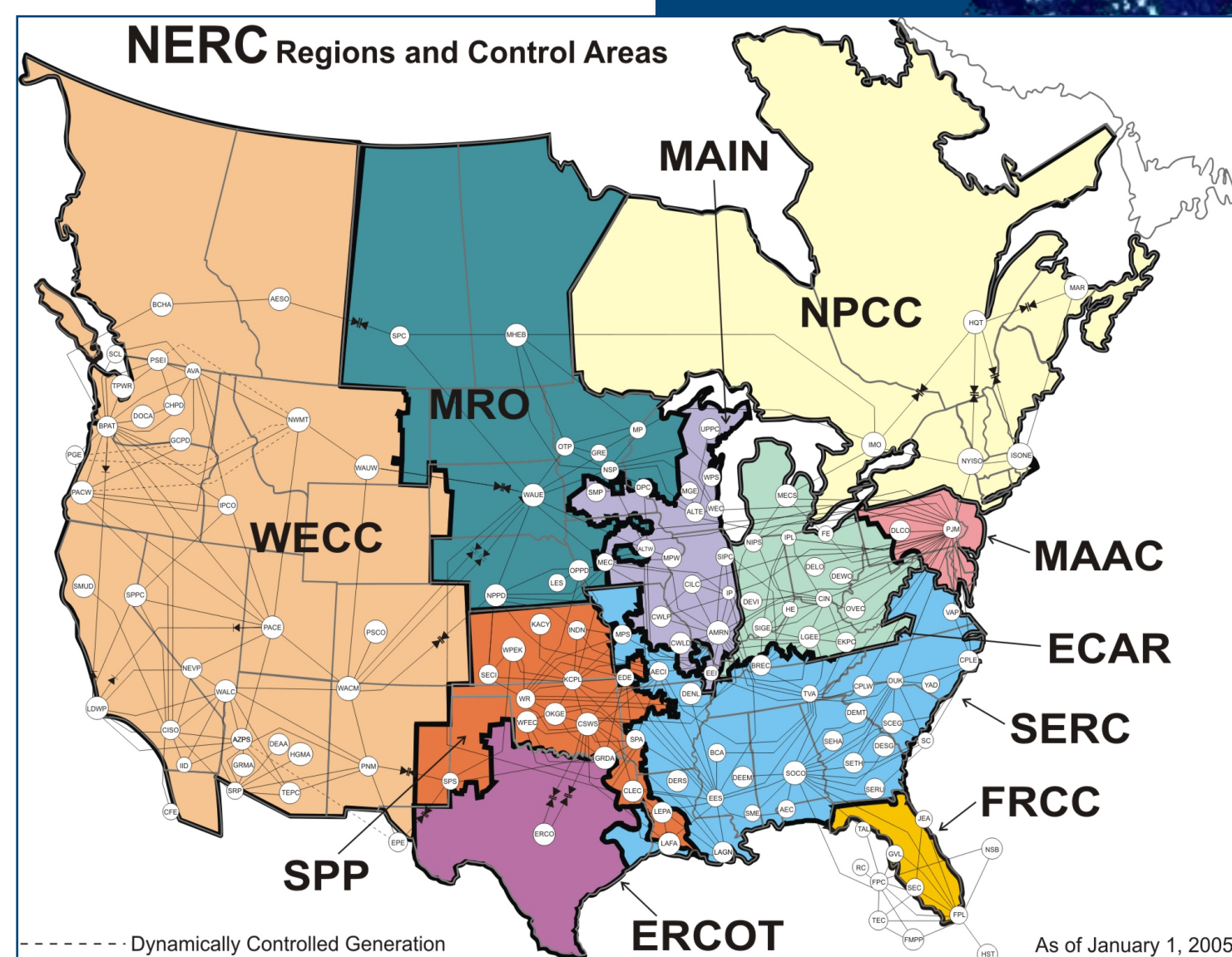
- Identify and evaluate key characteristics describing:
  - Control area reliability and ancillary services
  - Wind energy production
  - Hydropower resources and constraints.
- Formulate a model relating key characteristics for simple prediction of ancillary service costs.

## CONTROL AREA

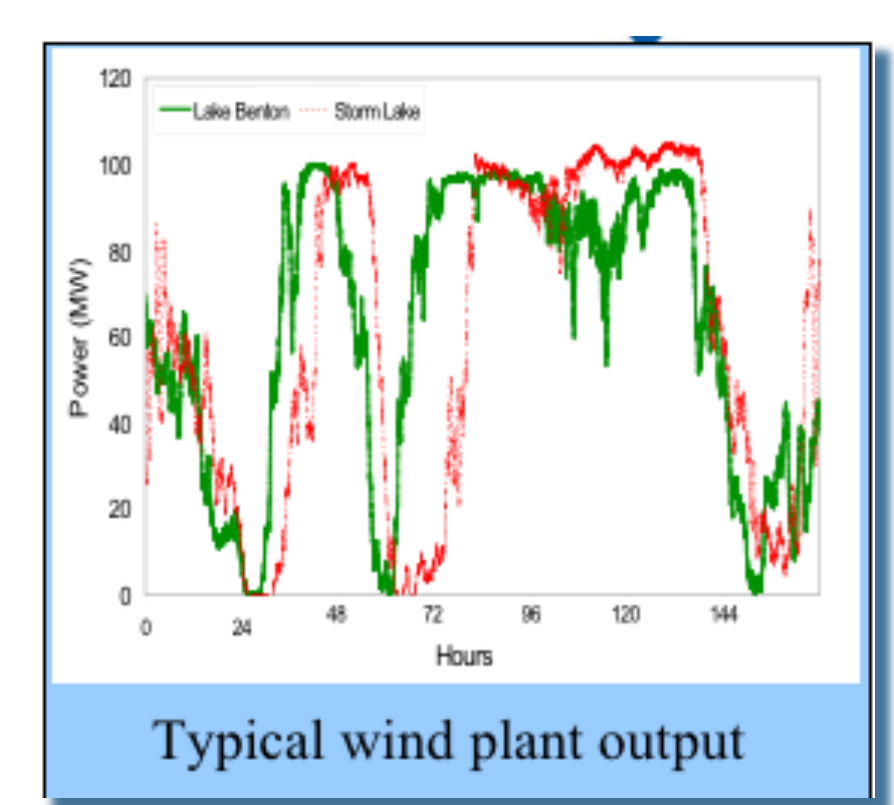
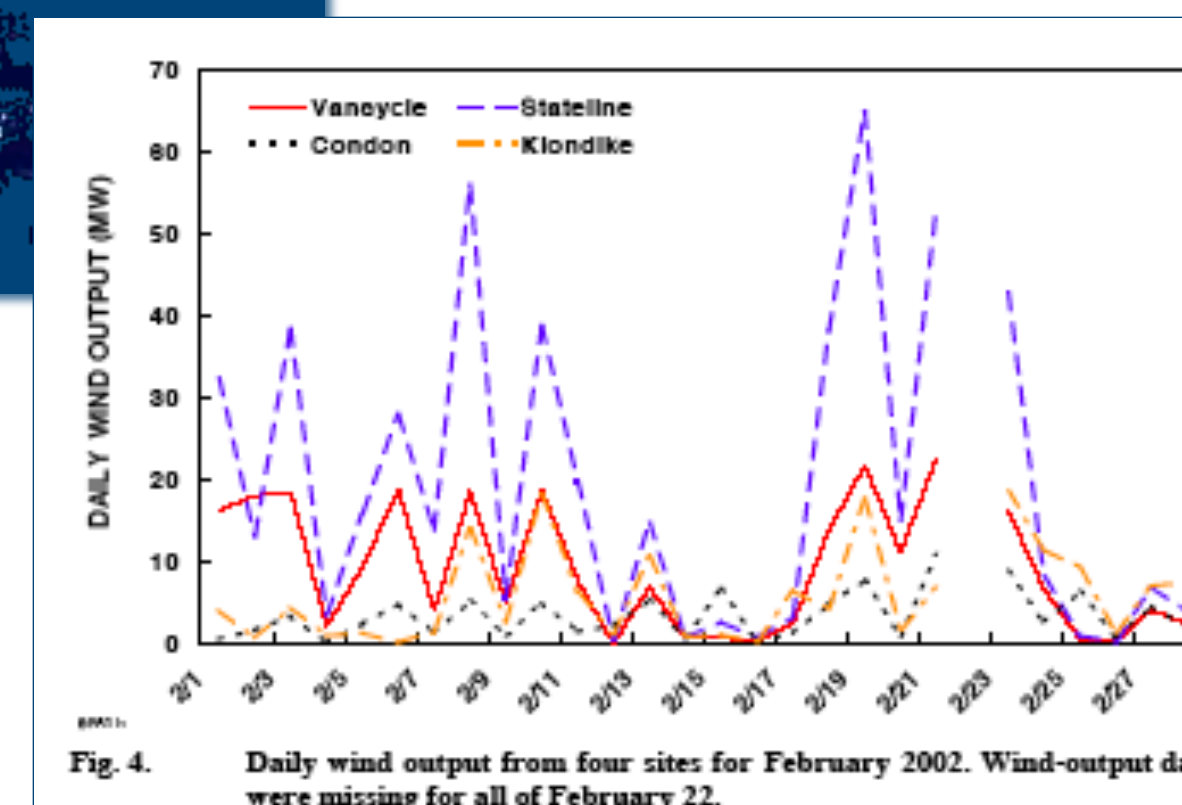
The U.S. electrical grid is managed by the North American Electric Reliability Council (NERC); a voluntary non-profit organization whose goal is to ensure a reliable, adequate and secure electric system.

NERC is made up of ten regional reliability councils whose members include: investor-owned utilities; federal power agencies; rural electric cooperatives; state, municipal and provincial utilities; independent power producers; power marketers; and end-use customers. There are 133 control areas within these regions.

Control areas are sub-regions of the electrical grid that are responsible for meeting the reliability standards set by NERC and ensuring there is sufficient generation capacity to meet the demand. A control area system operator must maintain voltage frequency and match power output to the load requirement, while maintaining system reliability.



## WIND



The charts above show the day to day<sup>1</sup> and hourly<sup>2</sup> variability of wind farm energy production. This inherent variability directly impacts the ancillary services required to integrate wind energy into the power grid.

<sup>1</sup> Integrating Wind Energy With The BPA Power System: Preliminary Study, Eric Hest, Consulting in Electric-Industry Restructuring, Oak Ridge, Tennessee 37830 September 2000  
<sup>2</sup> Integrating Renewable Energy With Hydro: Northern Arizona Resources and Lower Colorado River Dam.

## HYDROPOWER

The seasonal alternating availability of wind versus hydro is typical (see Fig. 6 at left\*) and a key reason for the synergistic benefits of integration. One of the key benefits for hydropower is reduced demand for water output during the dry season, as seen to the left in Fig. 4\*. Hydropower has several properties that make it an ideal source of ancillary services for a wind farm:

- Hydro generators are agile and can easily offer regulation and load following services.
- Energy storage capacity.

However, there are key constraints on hydropower that affect its ability to provide ancillary services: Water use priorities including flood control, irrigation, navigation, recreation, fish habitat and energy production. Large hydropower facilities are generally government-owned and answerable to a diverse group of constituencies; therefore any changes to water use require complex decision making processes.

\*Wind / Hydro Complementary Seasonal Regimes in Brazil, Odilon A. C. do Amarante, Dario J. Schultz\*, Rogério M. Bittencourt\*\* and Nelson A. Rocha\*\*\*, DEWI Magazin Nr. 19, August 2001.

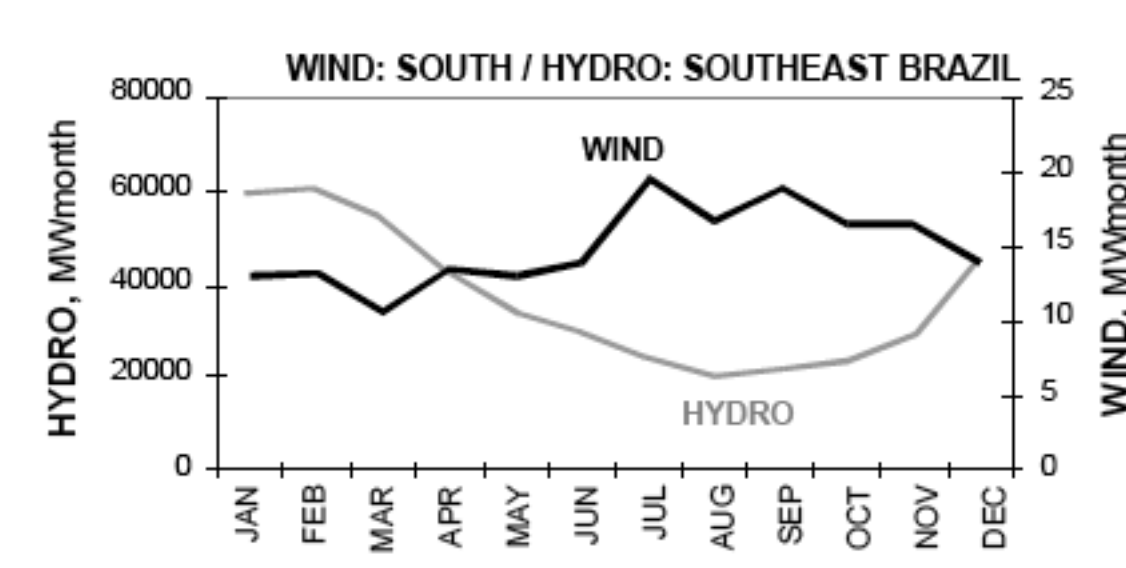


Fig. 6: Integration of a hypothetical Palmas 50 MW windfarm into the Southeastern Brazilian electrical sub-system.  
Fig. 6: Integração de uma usina eólica hipotética de 50 MW em Palmas nos subsistemas elétrico Sul/Sudeste.

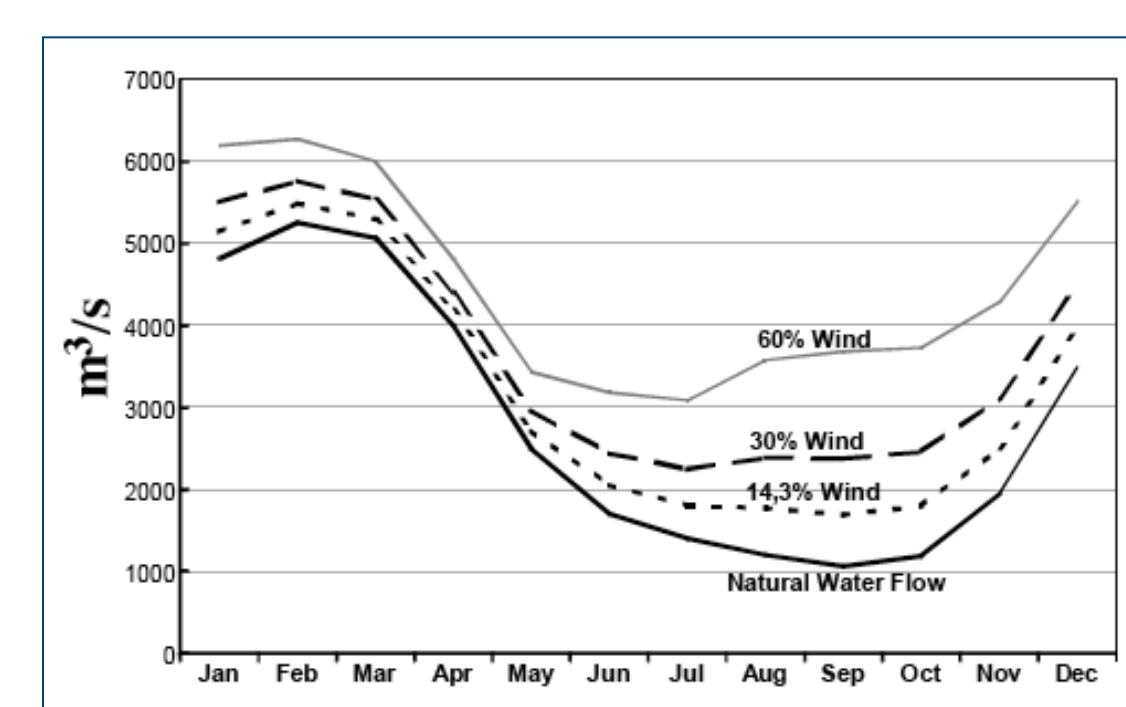


Fig. 4: Equivalent water inflow at Sobradinho with increasing wind energy penetration.  
Fig. 4: Vazão afluente equivalente (m³/s) no reservatório de Sobradinho correspondente à inserção de energia eólica.

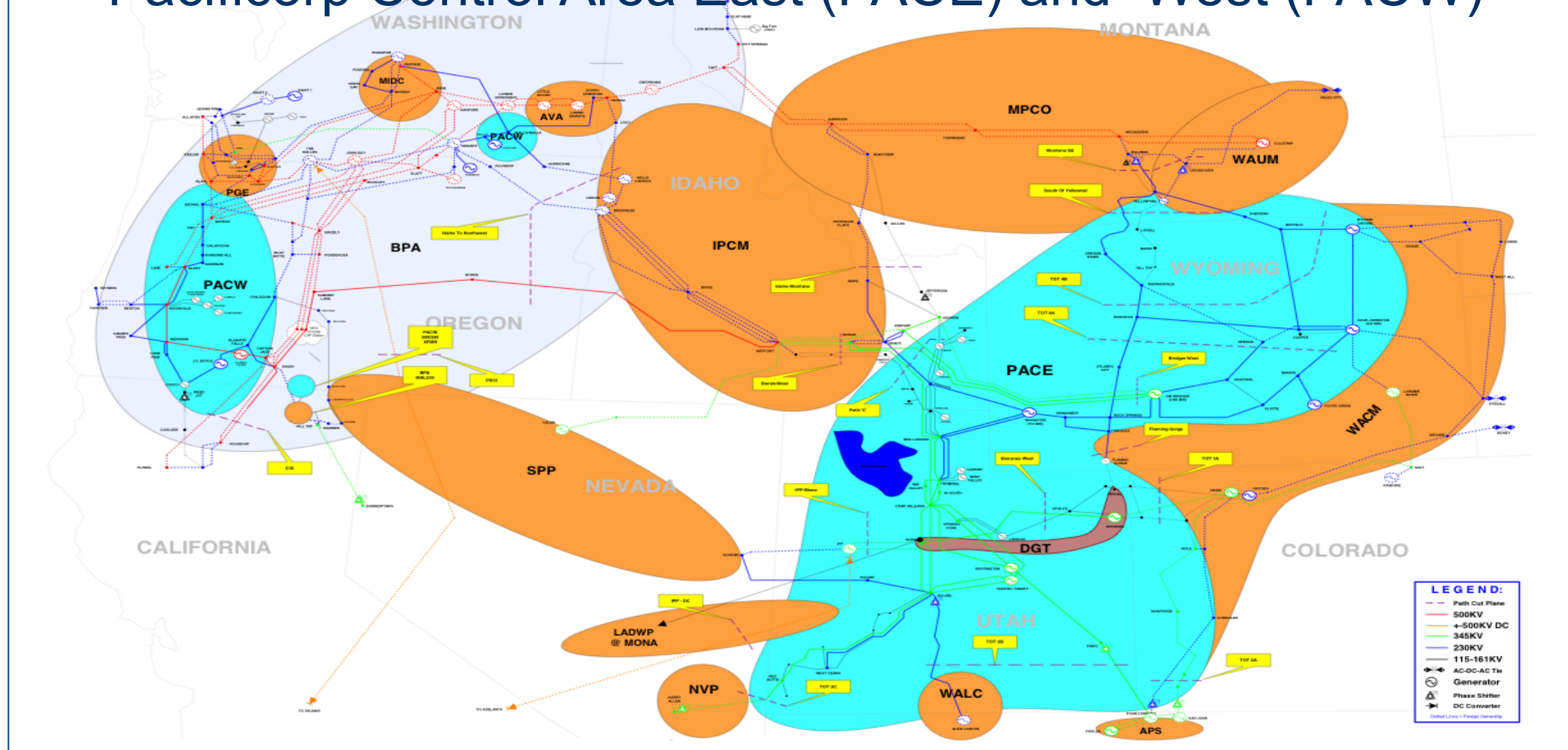
## ACCOMPLISHMENTS TO DATE:

- Identified all relevant control areas in the WECC
- Identified the principal sources of data for electrical generation in each control area
- Literature review of relevant wind power integration studies

## CHALLENGES AHEAD:

- Determine key control area indicators for simplified modeling (e.g. in terms of regulation, reserves, etc.) that are readily available
- Identify key wind energy output parameters for simplified modeling
- Identify key characteristics and constraints on hydropower facilities
- Formulate simple model to determine potential for wind/hydro integration.

## Pacificorp Control Area East (PACE) and West (PACW)



### PACIFICORP CAPACITY BY DISTRIBUTION

Data	Prime	Hydro	ST	Grand Total
NAMEPLATE CAPACITY	374	1141.1	7086.4	8601.5
CAPACITY < 5 MW	0	38	0	38
CAPACITY 5-10 MW	0	11	0	11
CAPACITY 10-50 MW	9	27	1	37
CAPACITY 50-100 MW	0	5	3	8
CAPACITY 100-150 MW	0	0	4	4
CAPACITY 150-200 MW	0	0	1	1
CAPACITY > 200 MW	0	0	14	14

GT = GAS TURBINE  
HY = HYDROPOWER  
ST = STEAM  
SOURCE: EIA 2003 FORM 860

Control areas are not generally contiguous, as can be seen above in the map of the Pacificorp Control Area<sup>1</sup>.

Pacificorp is one of 34 control areas within WECC.

In the year 2003 Pacificorp generated approximately 64,227,722 MWh of electricity<sup>2</sup>. The chart to the left shows Pacificorp's capacity distribution.

<sup>1</sup> [http://www.oasis.pacificorp.com/OASIS/PPW/pacificorp\\_path\\_map.pdf](http://www.oasis.pacificorp.com/OASIS/PPW/pacificorp_path_map.pdf)

<sup>2</sup> FERC Form 714 (2003): Annual Electric Control Area and Planning Area Report For the Year Ending December 31, 2003

The primary challenge in operating a control area is to ensure there is adequate capacity to meet the daily load requirements and to provide the additional capacity to match the unpredictable variation in the load that occurs on time scales from the near instantaneous to hours ahead. The graph on the left illustrates the three principal time frames of importance to a control area: less than a second, seconds to minutes, minutes to hours and days.

The near-second fluctuations in load must be met by near instantaneous responses that require automatic generation controls (AGC) and are termed regulation.

Minute to hour variation is matched by quick response generators and is called load following.

Daily load requirements requires major generation capacity and is termed unit commitment.

These are termed ancillary services and are part of the regulation burden for a power provider.

