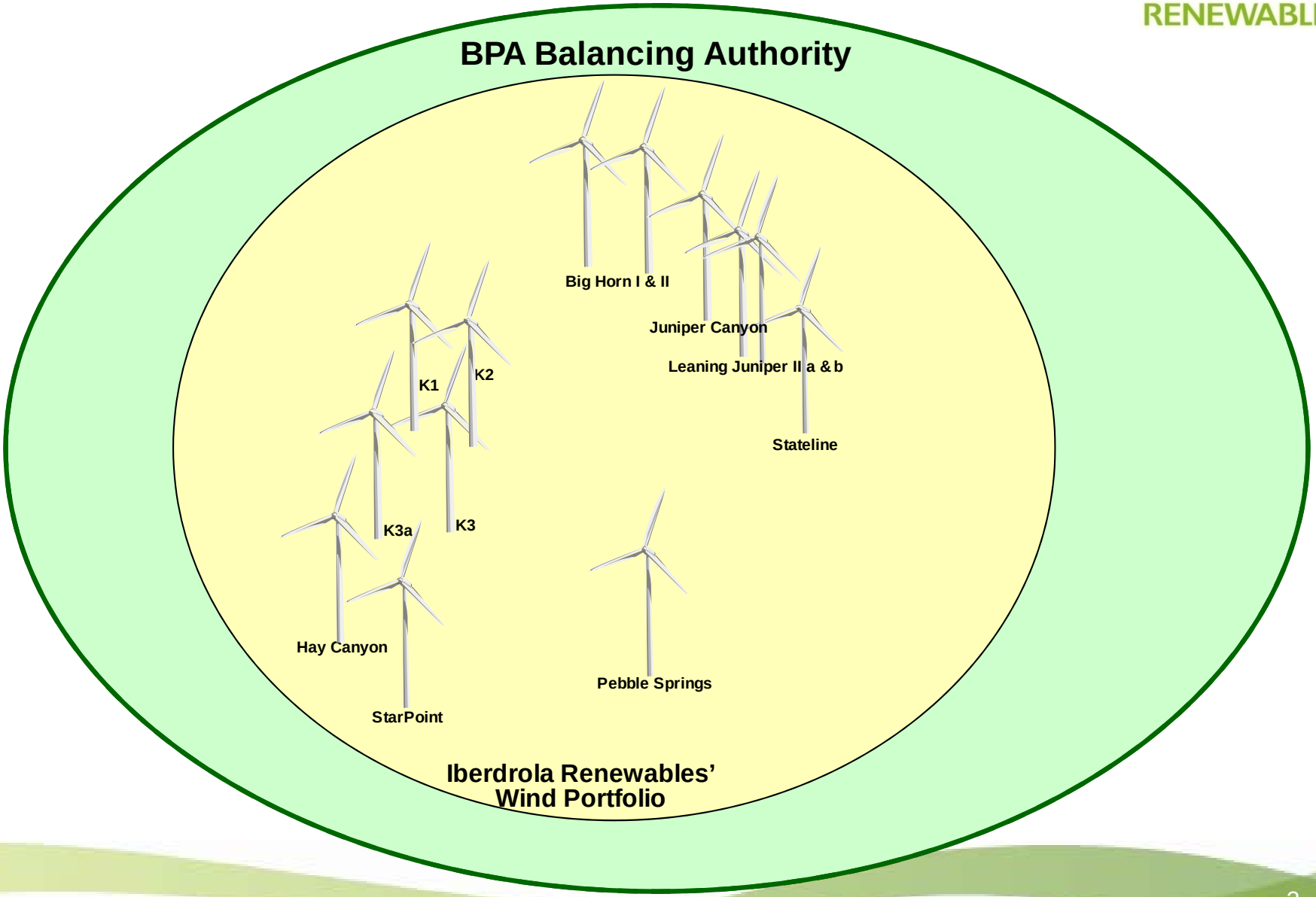
Voltage Control Capability in Bonneville's Balancing Authority Area

August 23, 2011

IBERDROLA RENEWABLES

Iberdrola Renewables Wind Portfolio



Voltage Control History

- Iberdrola Renewables' has designed and constructed wind generation facilities in accordance with the requirements under the LGIA
- Voltage control capability varies according to turbine technology as well as specific grid configuration.
- With greater penetration levels of wind generation on the grid, Bonneville has indicated a need for increased voltage control capability from Iberdrola Renewables' facilities
- Iberdrola Renewables has initiated a voltage control project to ensure the company's wind facilities can meet requirements

Voltage Control Summary

- Juniper Canyon
  - Turbine type: Mitsubishi 2.4 MW
  - Voltage control methodology: Full voltage control with droop capability

- Big Horn
  - Turbine type: GE 1.5 MW and Gamesa 2.0 MW
  - Voltage control methodology: Power factor mode due to relay tripping issues.

- Pebble Springs
  - Turbine type: Suzlon 2.1 MW
  - Voltage control methodology: VAr mode with voltage override

- Leaning Juniper II
  - Turbine type: Suzlon 2.1 MW and GE 1.5 MW
  - Voltage control methodology: Full voltage control with droop capability and switched caps controlled by the dynamic voltage controller

Voltage Control Summary

- The Klondikes
  - Turbine type: GE 1.5 MW & Siemens 2.3 MW
  - Voltage control methodology: Power factor mode due to coordination issues with multiple projects. Final voltage control scheme must be coordinated between all wind projects connecting at the John Day 230 kV bus and with the BPA 230 kV shunt caps at John Day

- Star Point
  - Turbine type: Suzlon 2.1 MW
  - Voltage control methodology: Power factor control with voltage override

- Hay Canyon
  - Turbine type: Suzlon 2.1 MW
  - Voltage control methodology: Power factor control with voltage override

Design Issues - Thermal

- The LGIA requirements are evolving and we have to design to the current requirements.
- Older Interconnection Agreements had a simpler requirements - power factor was be maintained at unity at the Point of Interconnection.
- We operate the turbines at unity power factor and we optimized the collector system design for delivery of real power only.
- Although the performance of the turbines has changed to include a power factor range of 0.95 lagging to 0.95 leading, as per interconnection requirements, it is still better for us to provide that compensation at the substation.
- There is some over-design in most collector systems and the variability of the wind allows us to handle some wider reactive requirements.
- We have to reduce the output of power for maximum reactive power through the collector system.
- Increasing the reactive carrying abilities of the collection to cope with the enhanced turbine abilities has a cost.

Design Issues - Control

- In terms of control, it is easier to control the reactive compensation at the substation.
- In particularly difficult conditions, we can rely employ a STATCOM - but at considerable cost.

Design Issues – Collector voltage boundaries

- Although on-line tap changers may be too slow for system disturbances, the lack of them can place us in a compromised position when reactive demand is made.
- Turbines at the end of the collector circuit experience greater variations of terminal voltage due to the greater impedance of the collector
- Reactive injection obviously raises the voltage and absorption lowers the voltage.
- Substation Step Up transformers are seldom fitted with on-line tap-changers for cost reasons.
- Generator Step Up transformers are off potential devices and provide little control.

Design – Voltage profiles.

- The impedance of the collector system and the generation level determine the voltage profile for the collector circuits. Accordingly, the tap setting of the Turbine Step Up transformer is set so that the turbine voltage limits are not breached. (This is about +/- 10% of the nominal voltage.).
- We must ensure that the voltage excursions do not result in turbine tripping.
- VAR002 voltage control requirement means that a greater effort for modeling the farm is required.