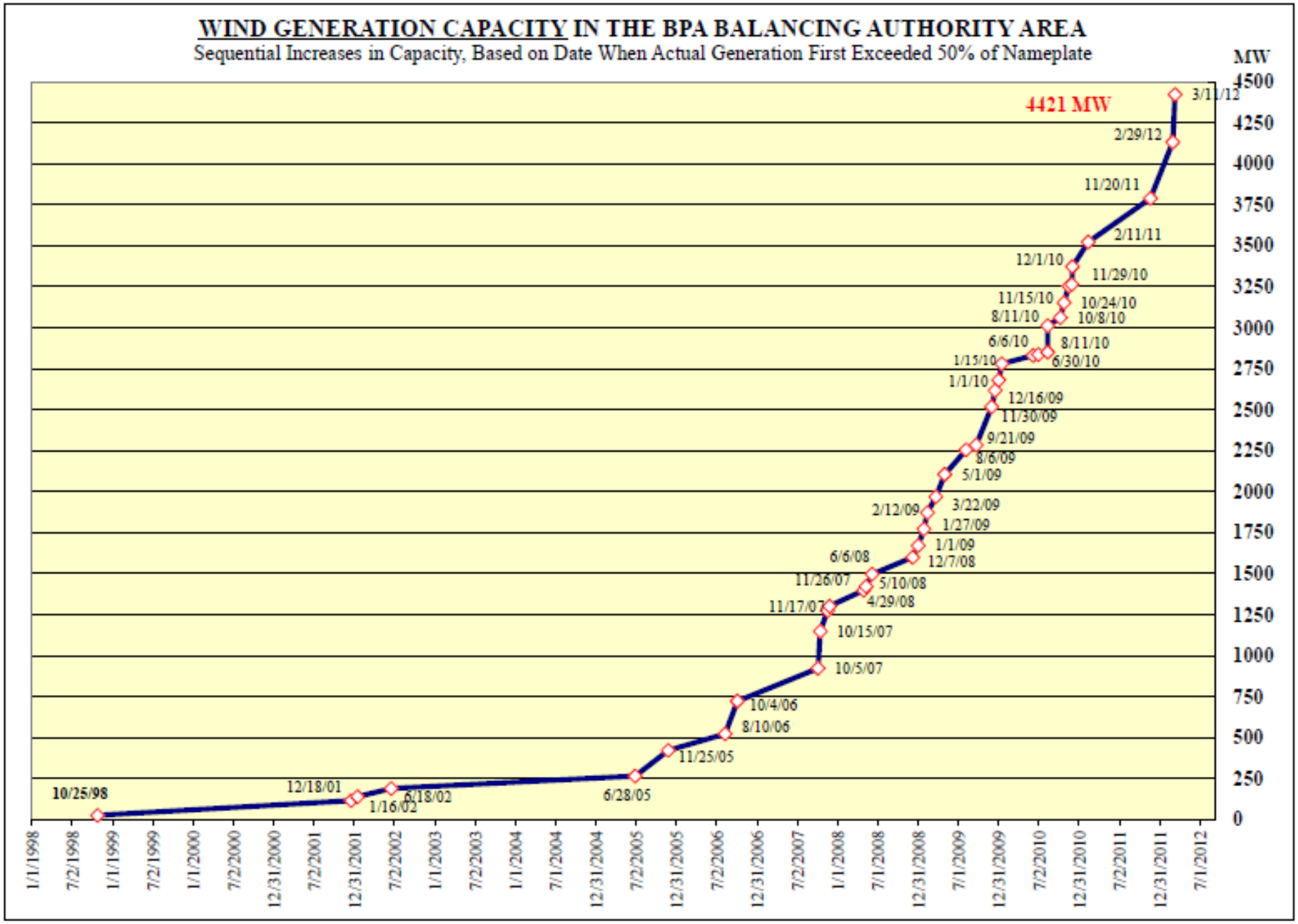
Using PMUs to Facilitate the Reliable Integration of Wind Generation in Pacific Northwest

NASPI Renewable Workshop

June 2012

Presented by Alison Silverstein for BPA


WIND GENERATION CAPACITY IN THE BPA BALANCING AUTHORITY AREA
Sequential Increases in Capacity, Based on Date When Actual Generation First Exceeded 50% of Nameplate
MW
4500
4250
4000
3750
3500
3250
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
4421 MW
3/11/12
2/29/12
11/20/11
2/11/11
12/1/10
11/29/10
11/15/10
10/24/10
8/11/10
10/8/10
6/6/10
8/11/10
1/15/10
6/30/10
1/1/10
12/16/09
11/30/09
9/21/09
8/6/09
5/1/09
2/12/09
3/22/09
1/27/09
1/1/09
12/7/08
6/6/08
11/26/07
5/10/08
11/17/07
4/29/08
10/15/07
10/5/07
10/4/06
8/10/06
11/25/05
10/25/98
12/18/01
1/16/02
6/18/02
6/28/05
1/1/1998
7/2/1998
1/1/1999
7/2/1999
1/1/2000
7/2/2000
12/31/2000
7/2/2001
12/31/2001
7/2/2002
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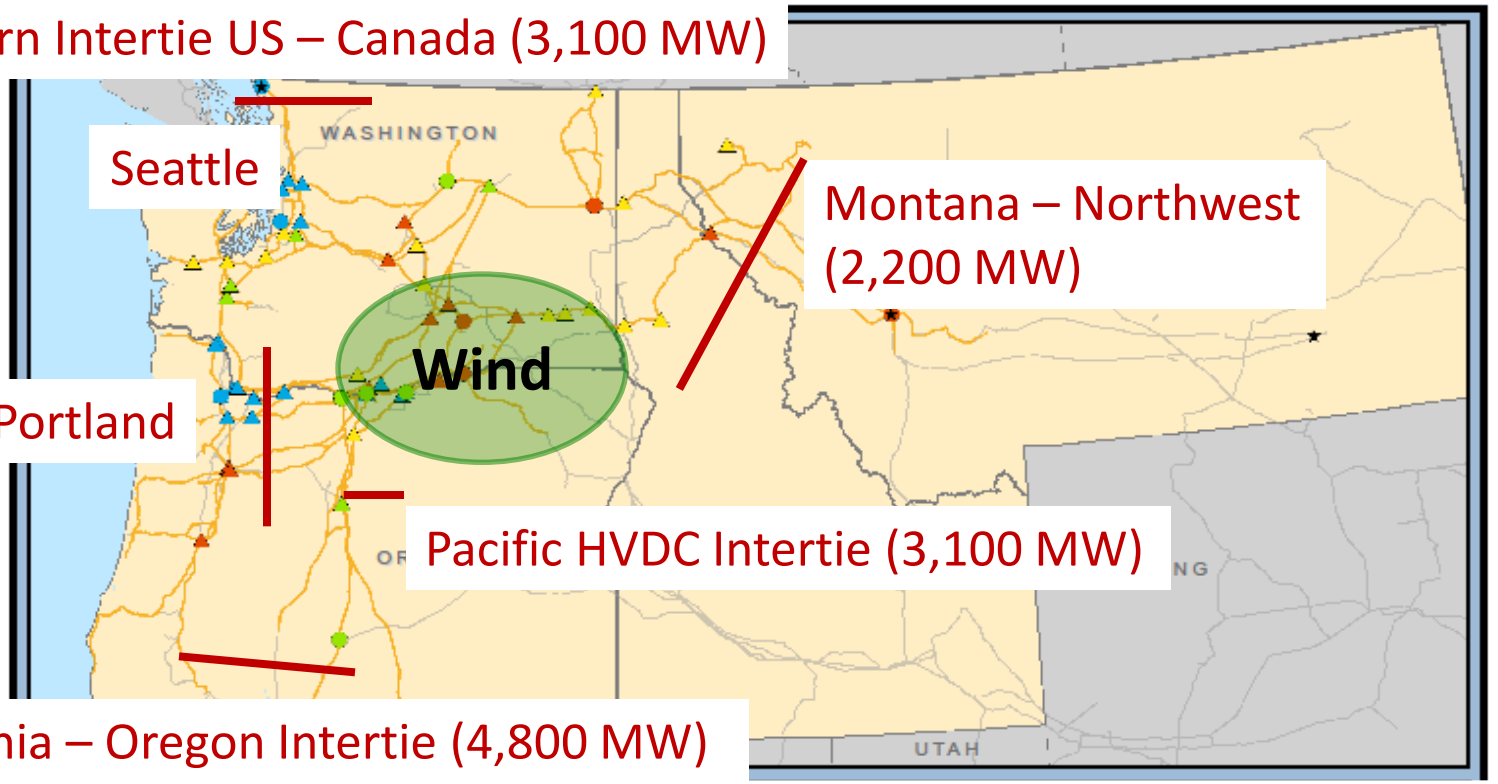
7/1/2008
12/31/2008
7/1/2009
12/31/2009
7/2/2010
12/31/2010
7/2/2011
12/31/2011
7/1/2012

Many of BPA Paths are Stability-Limited



BPA wind is highly correlated

- Installed capacity is about 4,400 MW
- Actual peak is above 4,000 MW in spring 2012

Challenges

1. Wind power plant models
2. Wind power plant voltage control
3. Wind hub voltage control coordination
4. Dynamic transfers

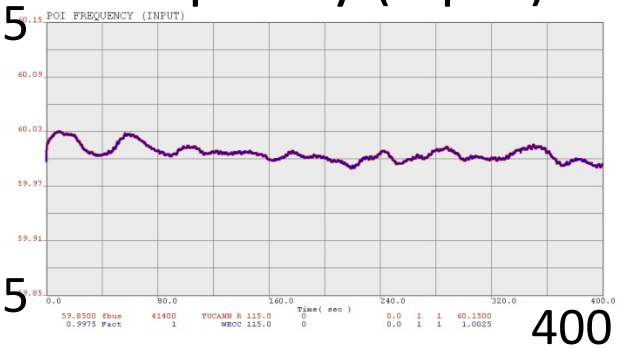
1. Wind Power Plant Modeling

- BPA has 4,500 MW of wind generation interconnected with no validated models
- Existing models failed to indicate some of the operational issues
- Type 2 generator models are particularly deficient (next slide)

Type 2 Wind Power Plant Model Validation

Frequency (input)

60.15

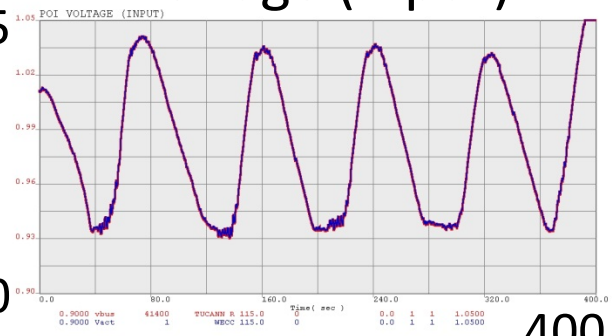


59.85

400 sec

Voltage (input)

1.05



0.90

400 sec

[0MW][COI 4799MW][IDAHO - SIERRA 258MW][IDAHO - MONTANA -270MW]
[0MW][0MW][0MW][ALTURAS PROJECT -58MW]
[WEST OF CASCADES - NORTH 3880MW][MIDWAY - LOS BANOS -301MW][PATH C -154MW][
[0MW][SOUTHERN NEW MEXICO (NM1) 184MW][CHOLLA - PINNACLE PEAK 848MW][INT
ALL COMMENTS RESULTING FROM THE OC & TSS REVIEW ARE INCLUDED.

Red = model

Blue = actual

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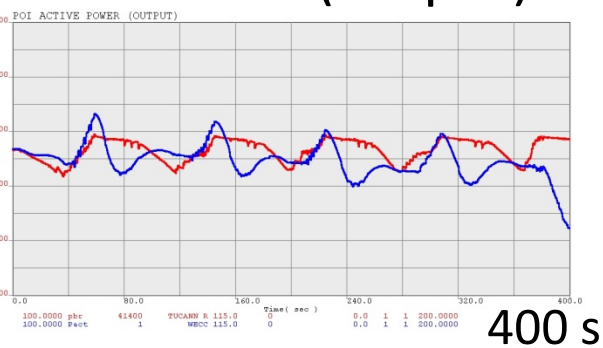
Sun Aug 21 18:38:46 2011

Plant MW (output)

200

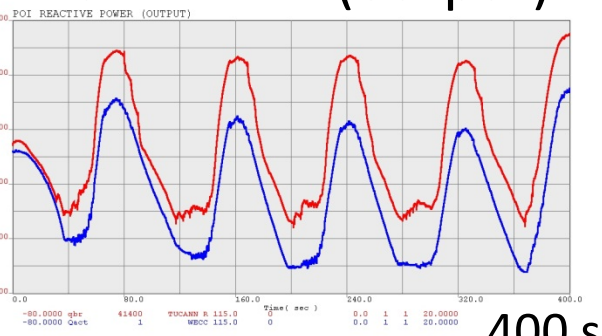


100

400 sec

Plant MVAr (output)

20



-80

400 sec

[0MW][COI 4799MW][IDAHO - SIERRA 258MW][IDAHO - MONTANA -270MW]
[0MW][0MW][0MW][ALTURAS PROJECT -58MW]
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NRW_2009_07_12_2308.chf

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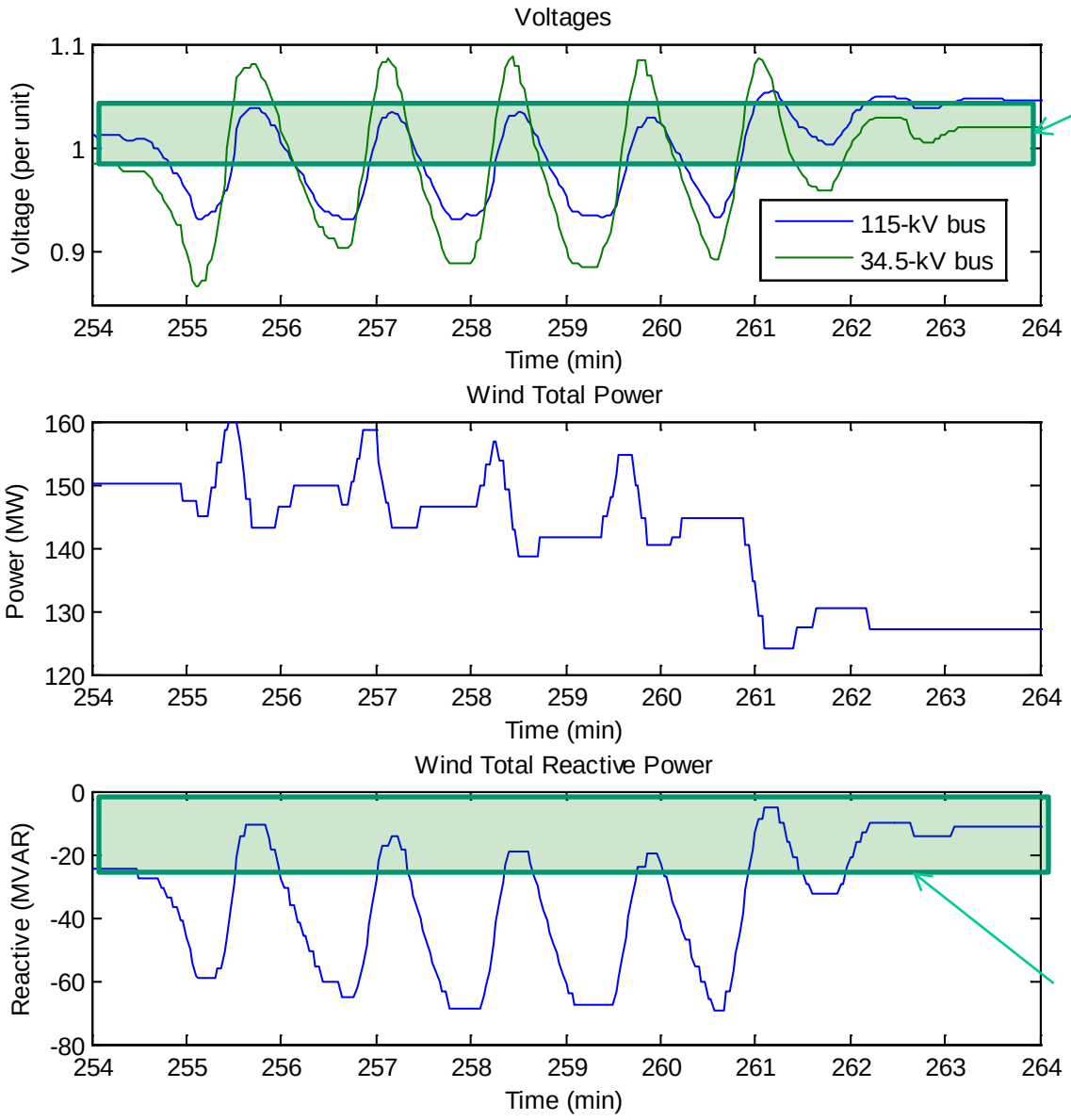
2. Wind Power Plant Voltage Control

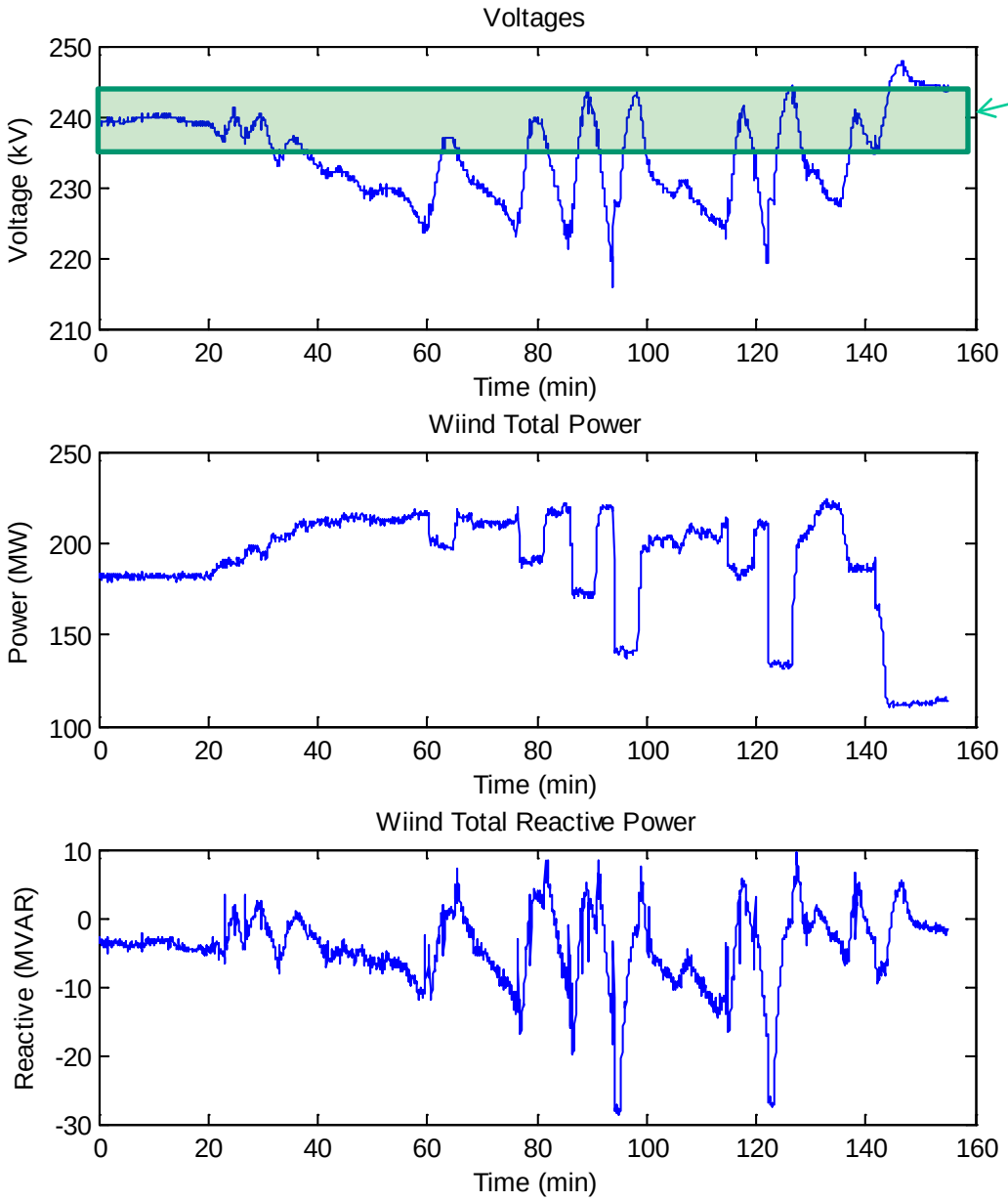
- LEGACY PLANTS:
  - Legacy plants (with type 1 and 2 technologies) do not have voltage control capabilities
  - Account for about 2,000 MW of capacity
  - The projects experienced a few operational issues, that were not identified in the planning studies (next two slides)



Normal operating range

Voltage and power oscillations at a type 2 wind power plant, July 2009

Required MVAR operating range



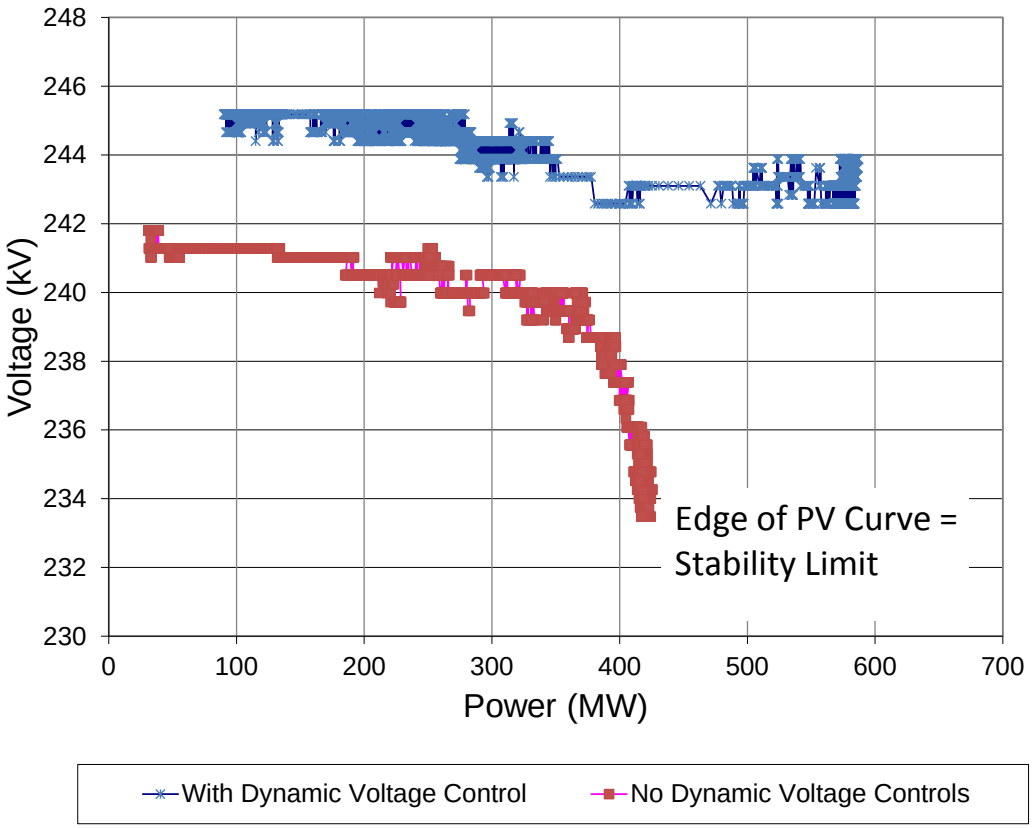
Normal operating range

Voltage and power oscillations at a wind hub with type 2 wind power plants and a type 3 plant in power factor mode, December 2010

2. Wind Power Plant Voltage Control

- NEWER PLANTS:
  - Type 3 and 4 generators are capable of voltage controls
  - CAN is not the same as WILL
  - Several plants do not have appropriate controls and operate in power factor mode => BPA is working with plant operators on enabling voltage control functions
  - Many new plants have adequate voltage control and provide adequate voltage support to the grid

Voltage Controls help to increase the amount of wind integration



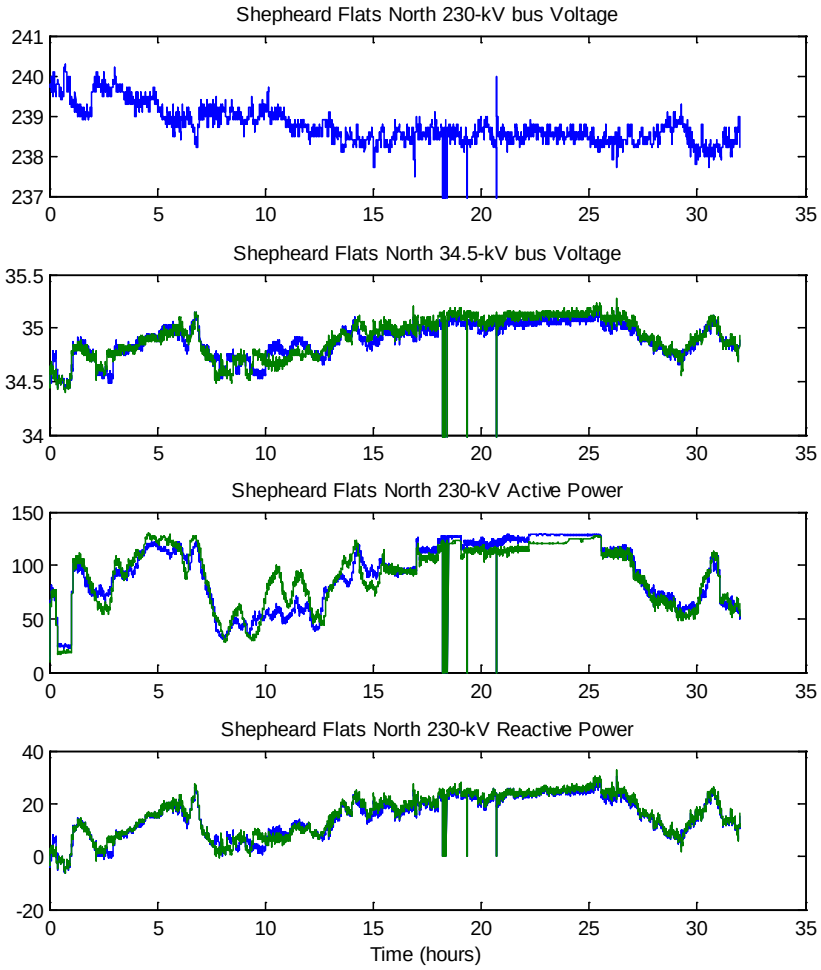
Wind hub reached a 420 MW voltage stability limit with no dynamic voltage control

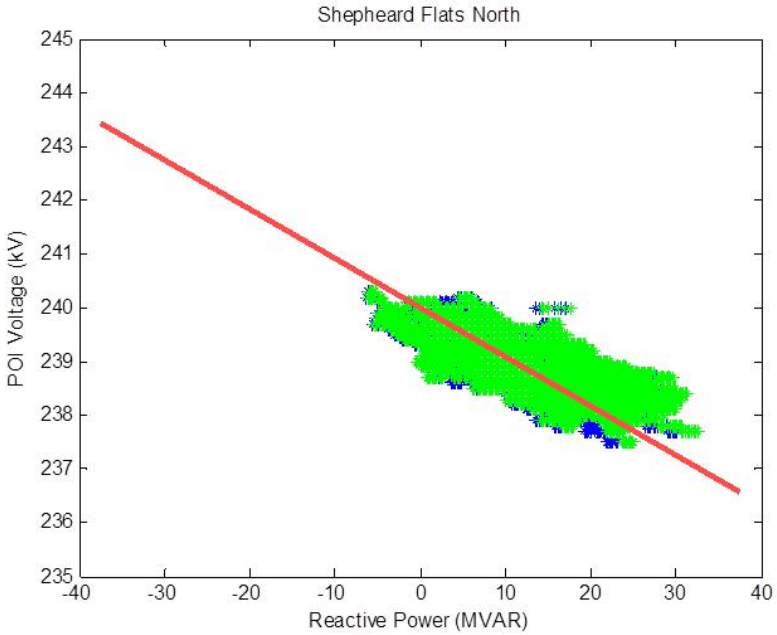
The hub generation is increased to 600 MW by adding 200 MW of generators with dynamic voltage control capabilities

3. Wind Hub Voltage Control Coordination

- BPA wind is highly concentrated
- Wind plants are clustered into large hubs
- Need to coordinate reactive power sharing among the plants
- New plants operating in voltage control have stable reactive power sharing
- Coordination with legacy technologies remains challenging

- New plants that have dynamic voltage control and operating in droop mode have stable and equitable reactive power sharing



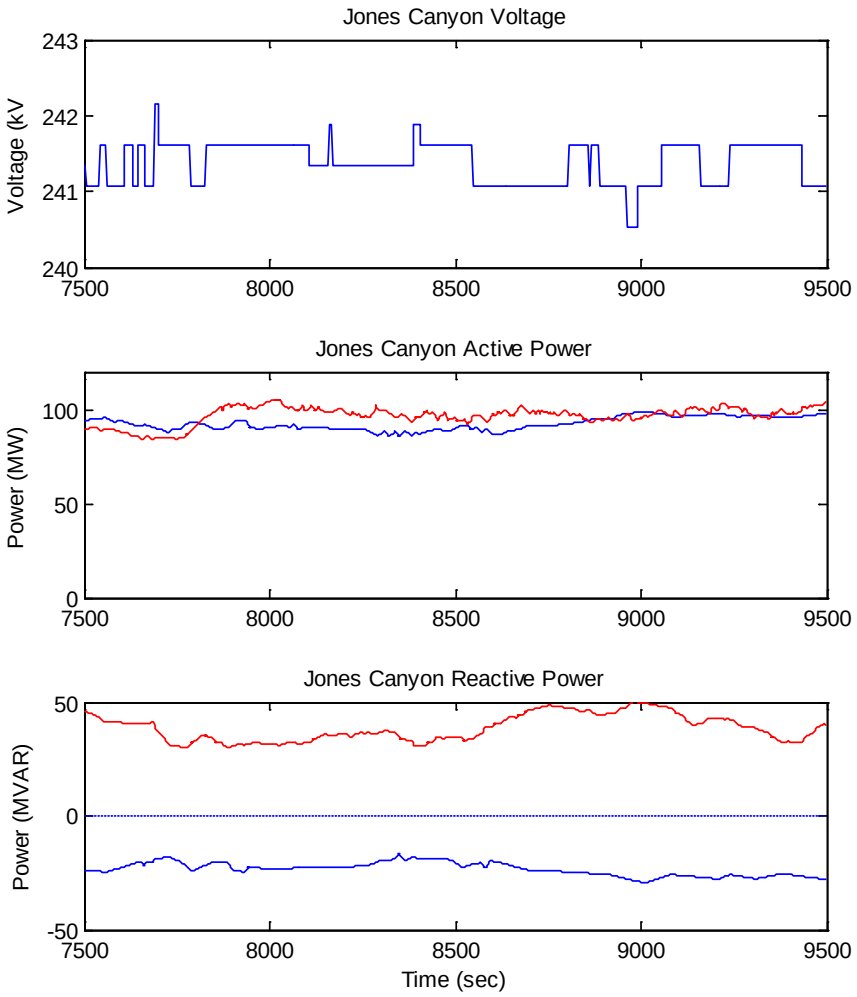


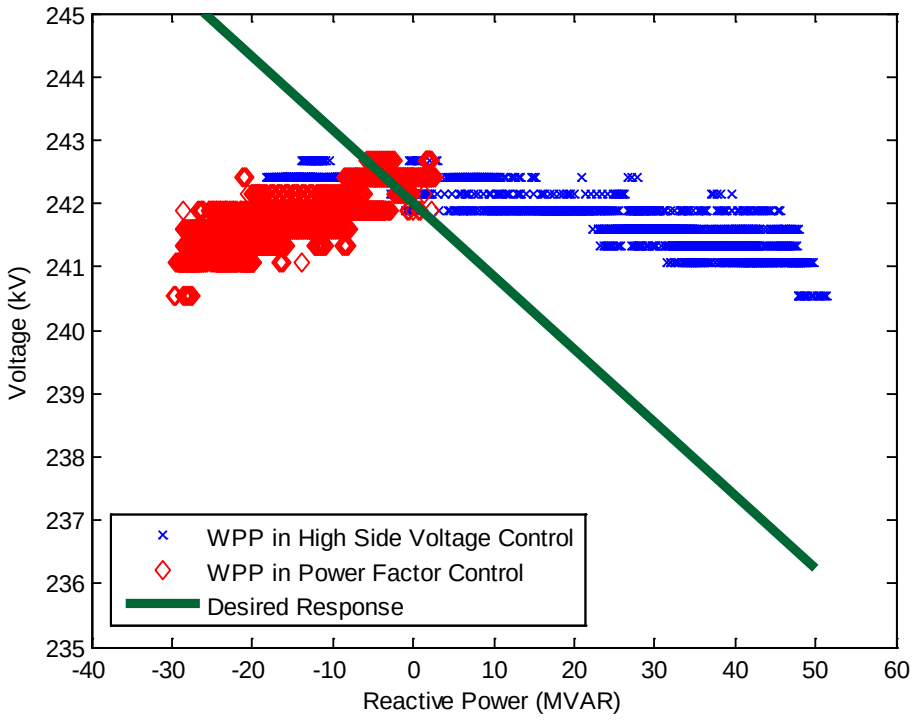
Blue = WPP1

Green = WPP2

Red = Desired

- Early wind plants that do not have voltage controls have operational challenges in sharing reactive power





4. Dynamic Transfers

- Wind is ramping up / down
  - BPA wind ramps are large and fast because of high concentration
- Conventional generation is used to balance wind generation
- Conventional generation is often far from the where the wind is (e.g. British Columbia, Montana, California)
- The power needs to travel across the stability-limited paths
- Need to make sure that the system adjustments are keeping up with the dynamic transfers

Solutions and how Synchro-phasors can help

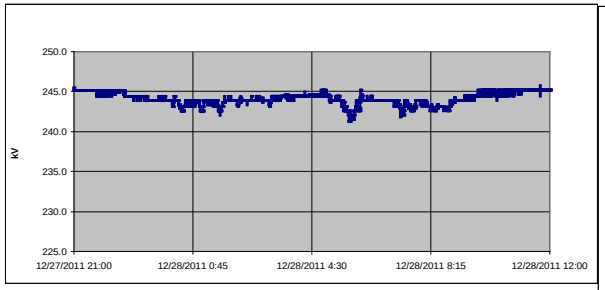
1. Wind Power Plant Modeling

- BPA is installing PMUs at wind power plants
  - Data from 15 plants is expected in April 2013
- PMU data will be used for wind power plant model validation
- BPA is supporting NREL-UVGIG project on wind power plant model validation

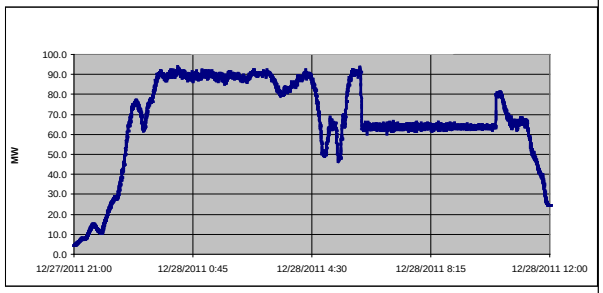
2. Wind Power Plant Voltage Control

- BPA is working with WPP operators on upgrading their voltage controls
- Trust but verify. BPA has developed OSI-Soft PI application for voltage control monitoring

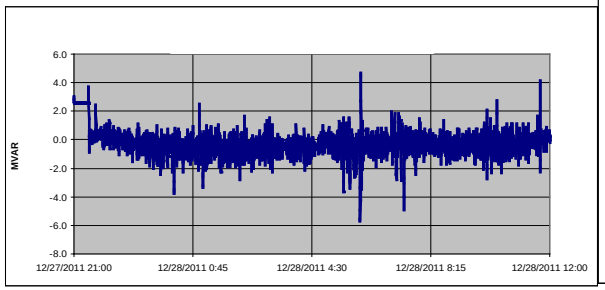
Voltage

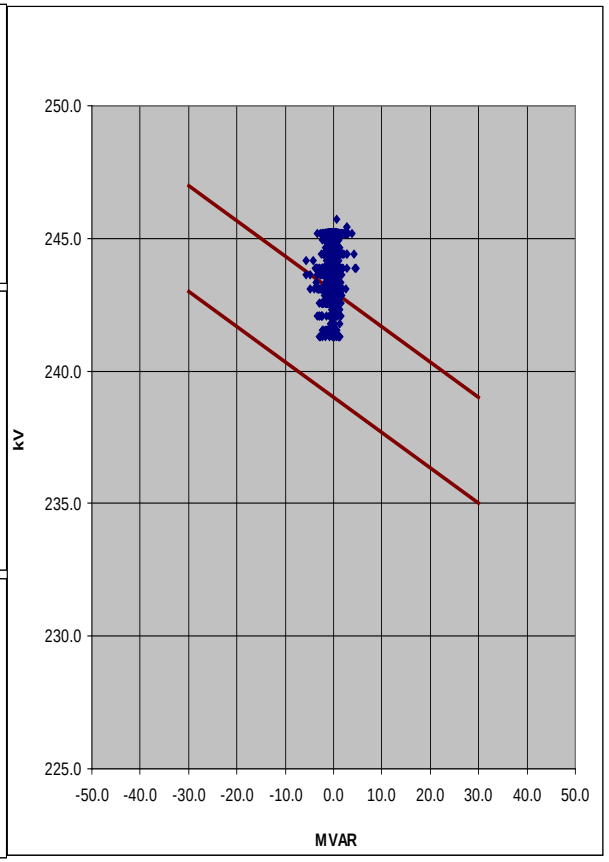


Active Power



Reactive Power





V-Q control:
Red = desired
Blue = actual

Power plant is in powerfactor control

3. Wind Hub Voltage Coordination

- PMU measurements can be used for wind hub voltage control and reactive power coordination
- How … Studies are in process

4. Dynamic Transfers

- Reliability starts with good planning. BPA is developing time-sequence powerflow capabilities to study voltage stability impacts of fast wind ramps.
- PMU measurements will provide better situational awareness for dispatchers to track voltage stability during fast wind ramps
  - Model-based VSA, similar to V&R ROSE
  - Measurement-based approaches
- Voltage stability controls – reactive switching

BPA Contacts

- Terry Oliver, tvoliver@bpa.gov,
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- Dmitry Kosterev, dnkosterev@bpa.gov,
  - BPA Transmission Planning – voltage control, modeling and monitoring