Introduction on the Voltage Control Conference

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Voltage Control – Session Overview

1. Grid operator's perspective on voltage control requirements and operational experiences in the Pacific Northwest

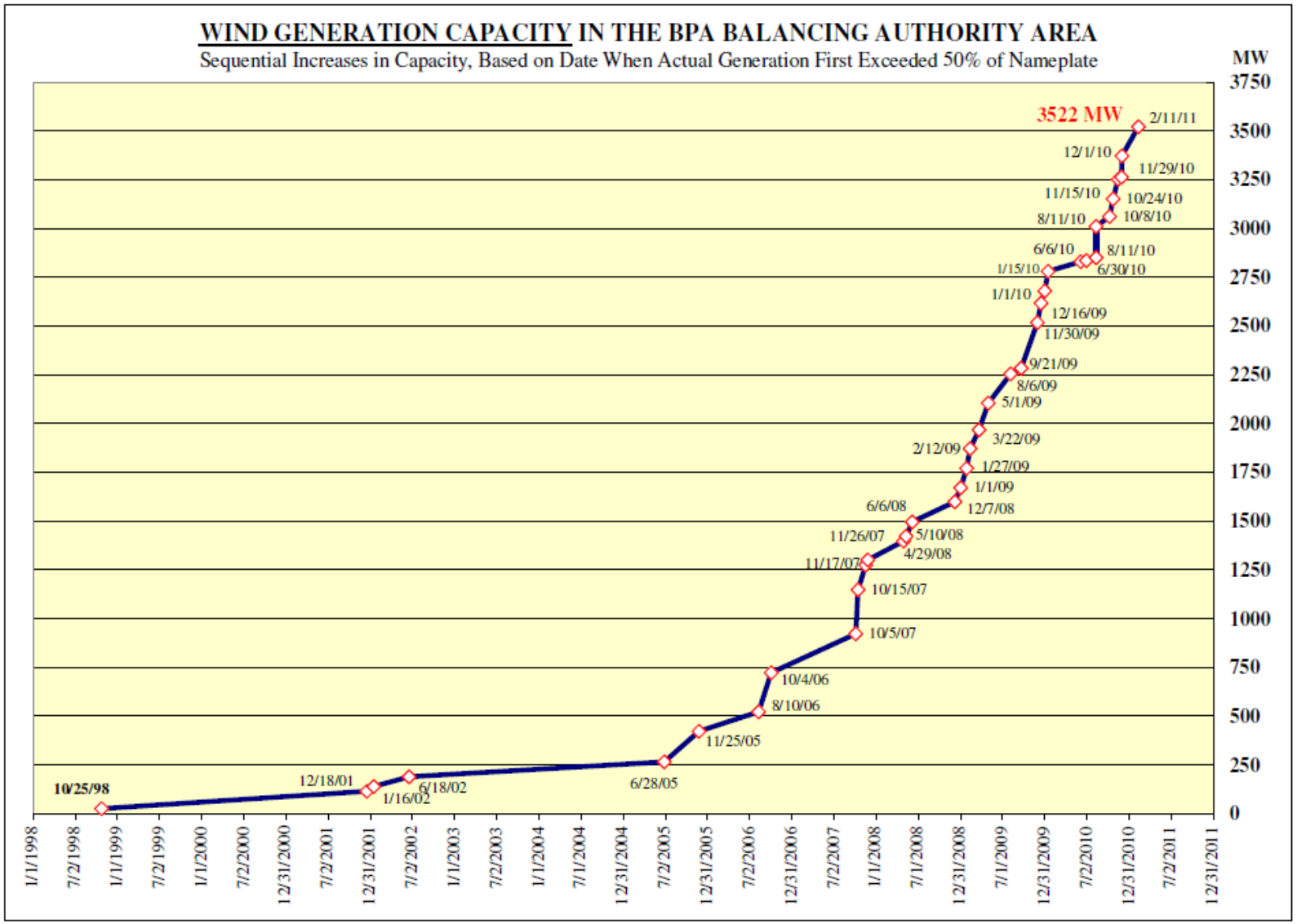
2. Manufacturer's perspective on voltage control and equipment capabilities

3. Wind power plant operator's perspective on voltage control

Presentation Subject

- The presentation focus is on control needs for “stability” time frame – i.e. making sure that the power system survives and performs during the power system disturbances
- Specifically, the presentation will focus on:
  - Voltage stability and controls
  - Monitoring and modeling
- The presentation will NOT discuss:
  - Wind generation balancing and regulation (“capacity”)
  - New transmission needed to accommodate wind

Wind in 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
3750
3500
3250
3000
2750
2500
2250
2000
1750
1500
1250
1000
750
500
250
0
3522 MW
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
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11/26/07
4/29/08
11/17/07
10/15/07
10/5/07
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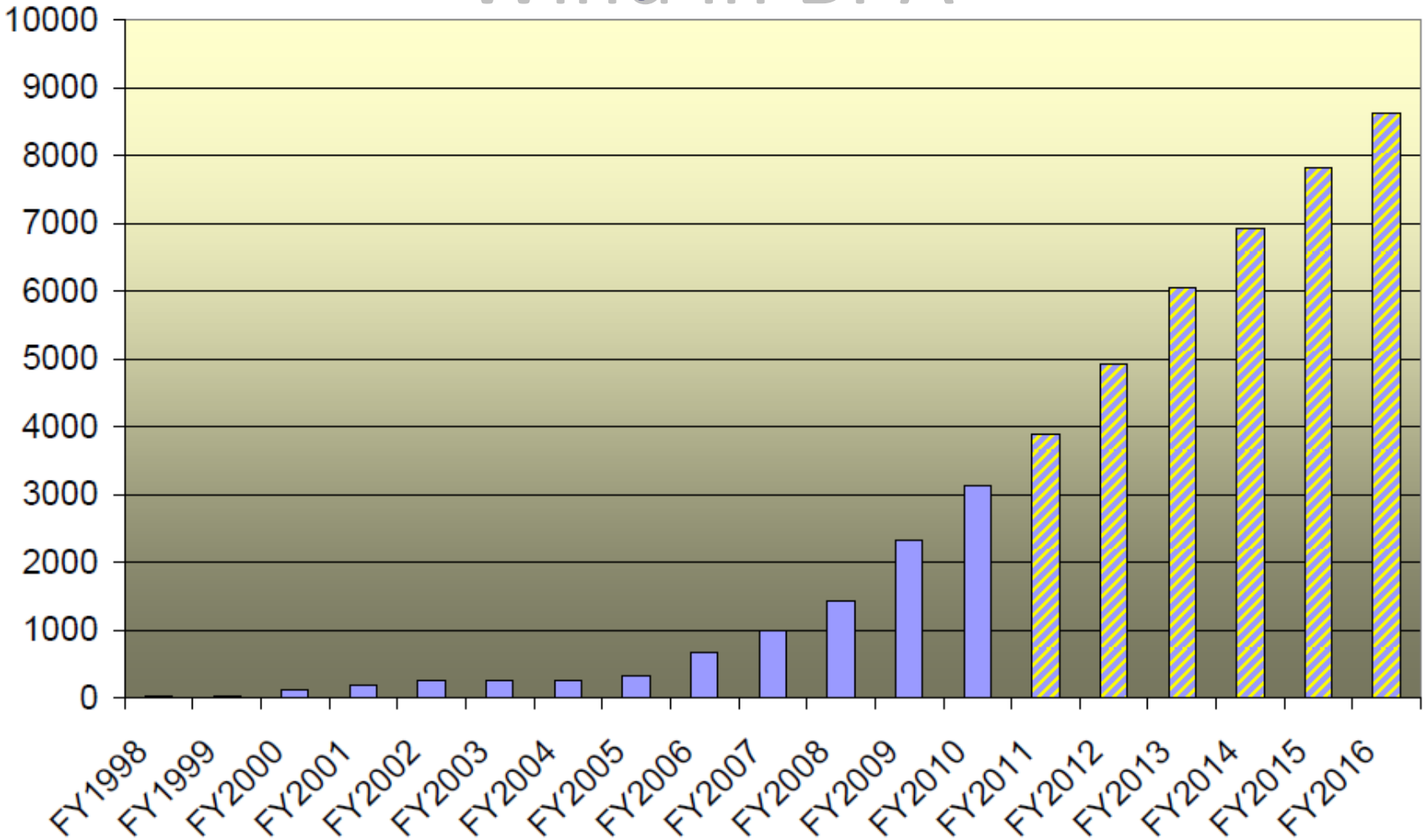
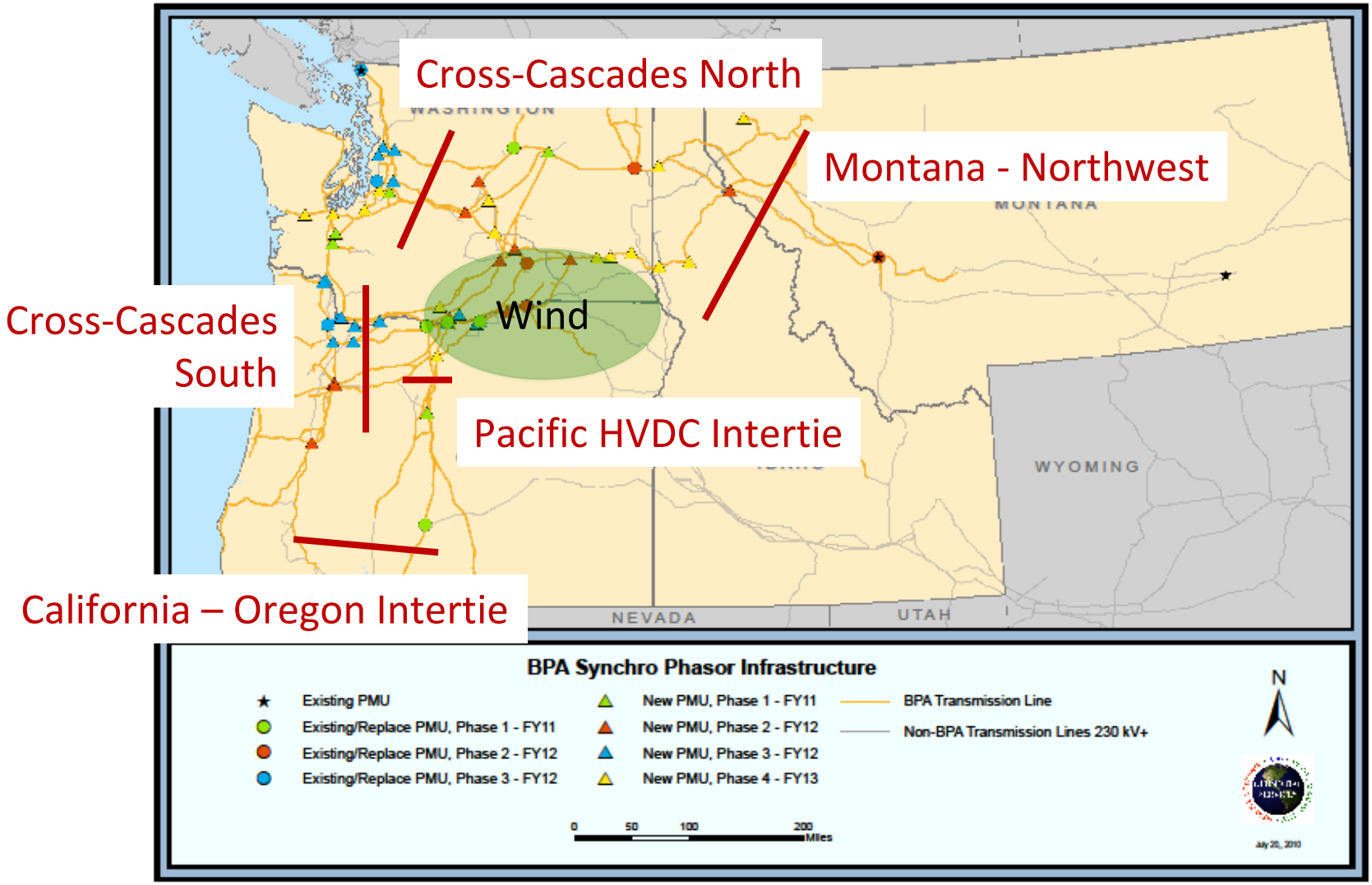
7/2/2011
12/31/2011

Wind in BPA



Renewable Generation Interconnection Projects to BPA Grid (Oct 1 - Sept 30)
(Note: Graph presents MW interconnected and Forecast, some may not be in BPA BAA)

Many of BPA Paths are Stability-Limited

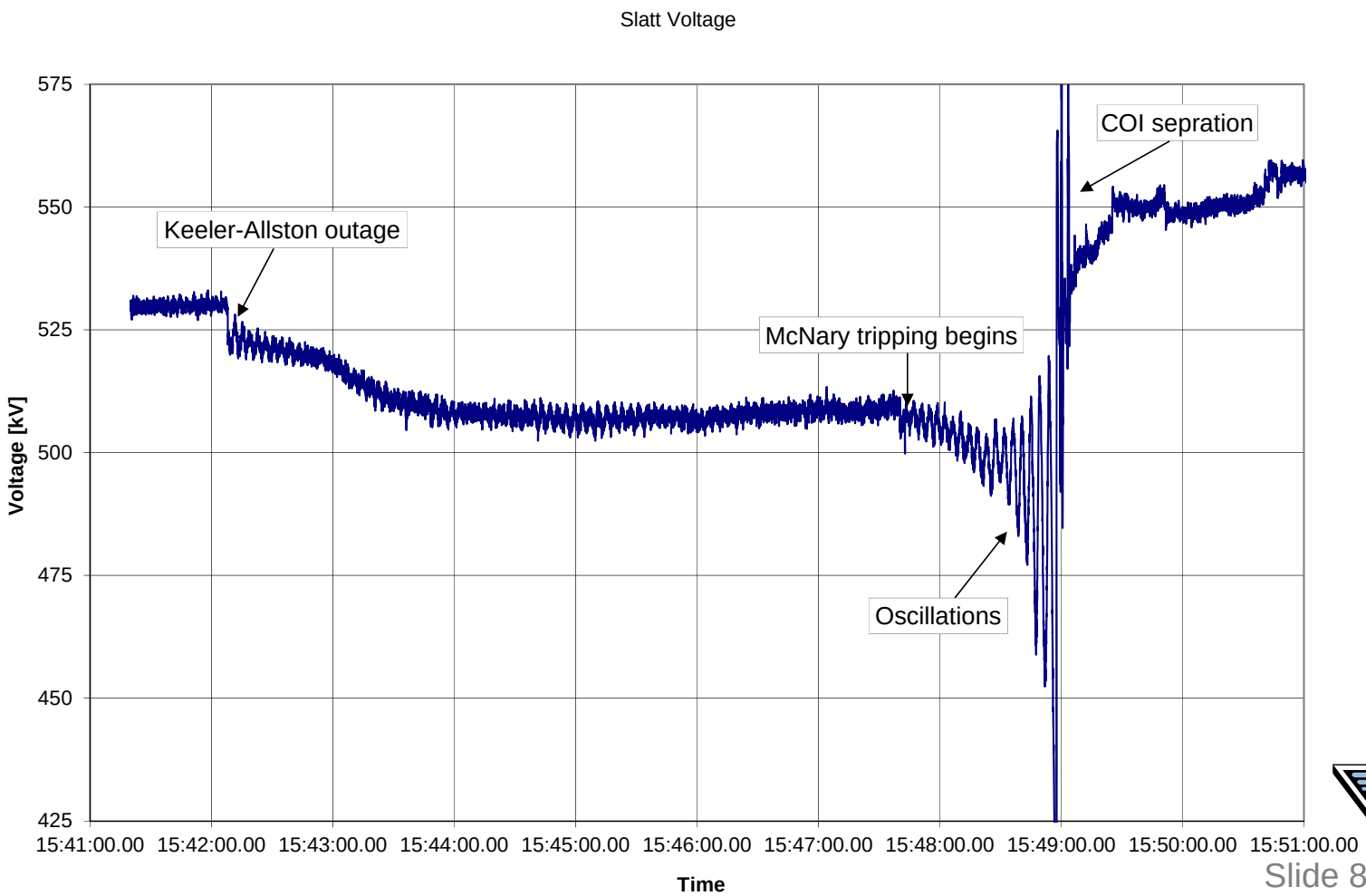


Pacific AC and DC Interties

- California – Oregon Intertie (COI) – three AC lines from Pacific Northwest to Northern California
  - rated at 4,800 MW
- Pacific HVDC Intertie (PDCI) – a two-pole DC line from Pacific Northwest to Los Angeles
  - rated at 3,100 MW
- Operating limits are usually lower, mainly due to voltage stability constraints

August 10 1996 Outage

"Those who forget the past are condemned to repeat it"



August 10 1996 Outage

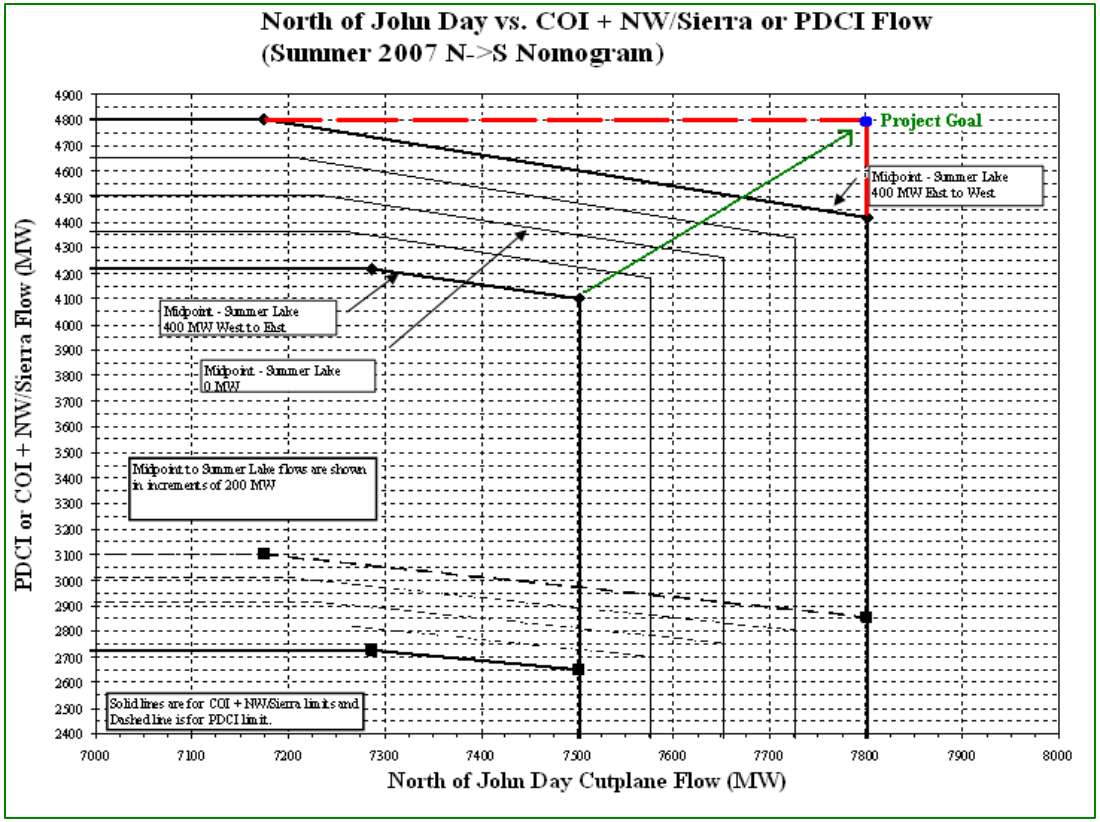
- Lessons learned:
  - There are interactions among several transmission paths in Pacific Northwest, on-line generation and load levels
  - Dynamic reactive reserves in lower Columbia are critical to support the high power transfers
  - Operating in POWER FACTOR instead of VOLTAGE control is highly detrimental
- Outage
  - A combination of voltage collapse and unstable oscillations resulted in COI separation and PDCI shutdown
  - 28,000 MW of load lost, 7.5 million customers

Impact of August 10 1996 Outage

- Interties were de-rated:
  - COI was de-rated by 33%
  - PDCI was de-rated by 33%
- Significant investments were made by BPA to improve voltage stability in the Pacific Northwest
  - Synchronous condenser capabilities at two Lower Columbia plants
  - Shunt capacitor additions
  - AC Reactive RAS and Fast AC Reactive Insertion
  - PDCI control modification
- Operating procedures
  - COI / PDCI Operating Nomogram
  - Dynamic reserve monitoring for generators in Lower Columbia
  - Equivalent unit monitoring for voltage swing support

Pacific AC and DC Interties

- Typical COI + PDCI Operating Nomogram



- 2011 BPA invested into Bakeoven series capacitors in both John Day – Grizzly lines to improve power delivery to COI

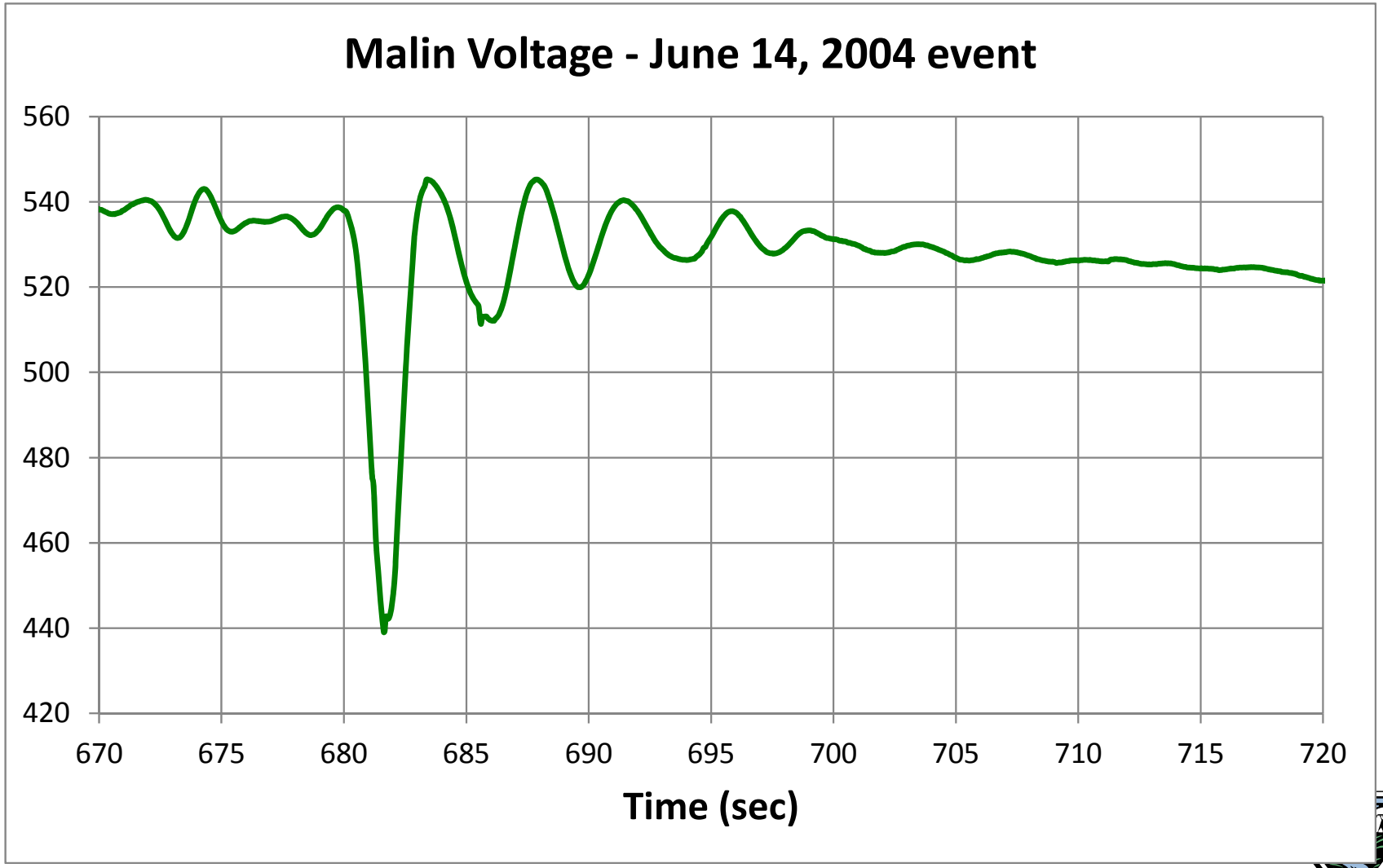
Reliability Standards

- We plan and operate the power system to meet the Reliability Standards, which set system performance criteria for normal and outage conditions
- Reliability sanctions – we live in the world of mandatory reliability standards as a result of the 2003 Northeast blackout
  - February 26, 2008 Florida outage:
  - 3,560 MW of load and 4,300 MW of generation
  - FPL settled with FERC for $25M, ($10M – US Treasury, $10M – NERC, $5M – reliability improvements)
  - Florida Public Service Commission asked FPL to refund $13.9 M to affected customers

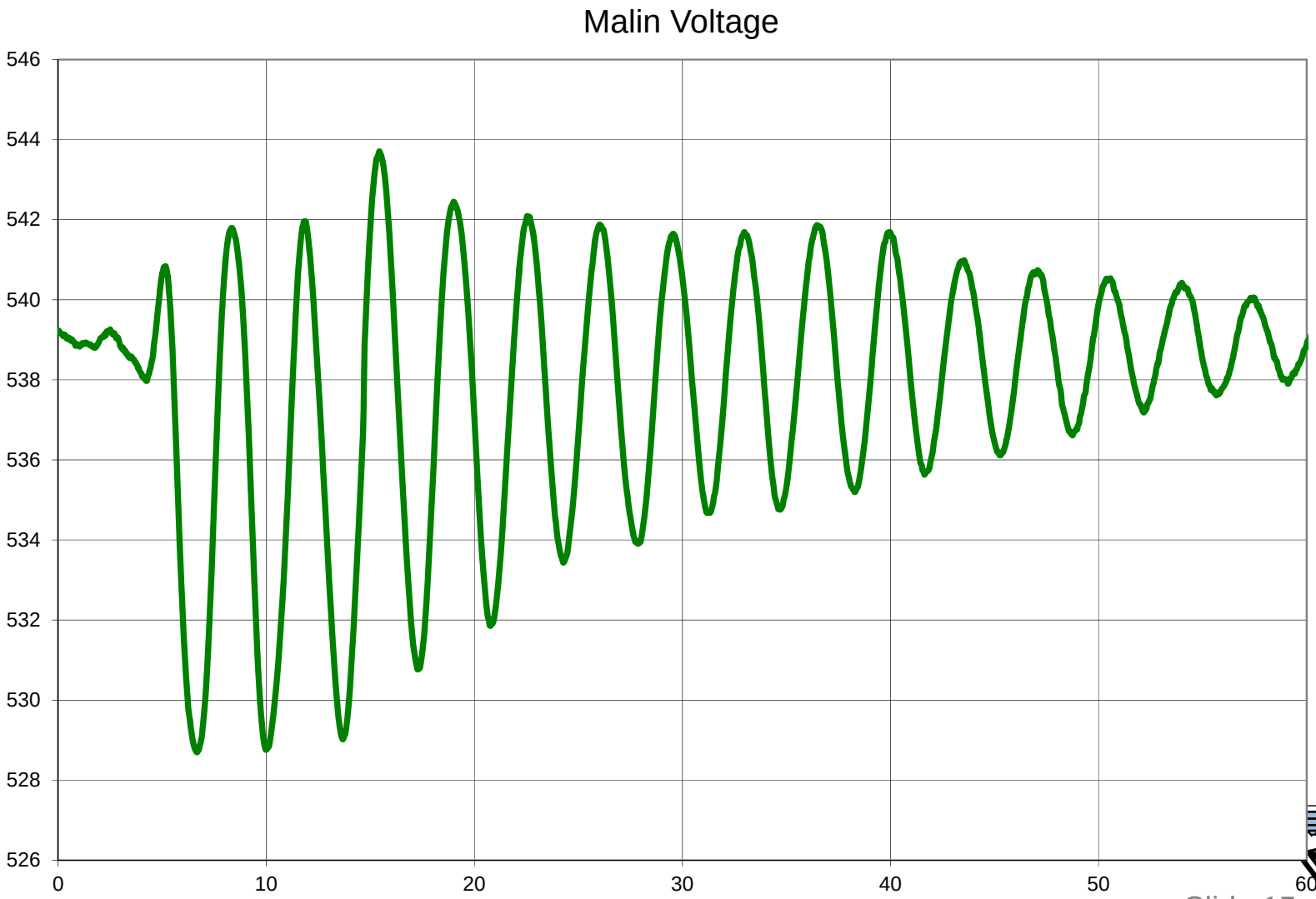
Voltage Control

- Voltage control goes beyond maintaining plant voltages during power ramps
  - This is given
- Voltage control is helping the system to survive "macro" disturbances
  - the system ability to survive disturbance sets that System Operating Limits

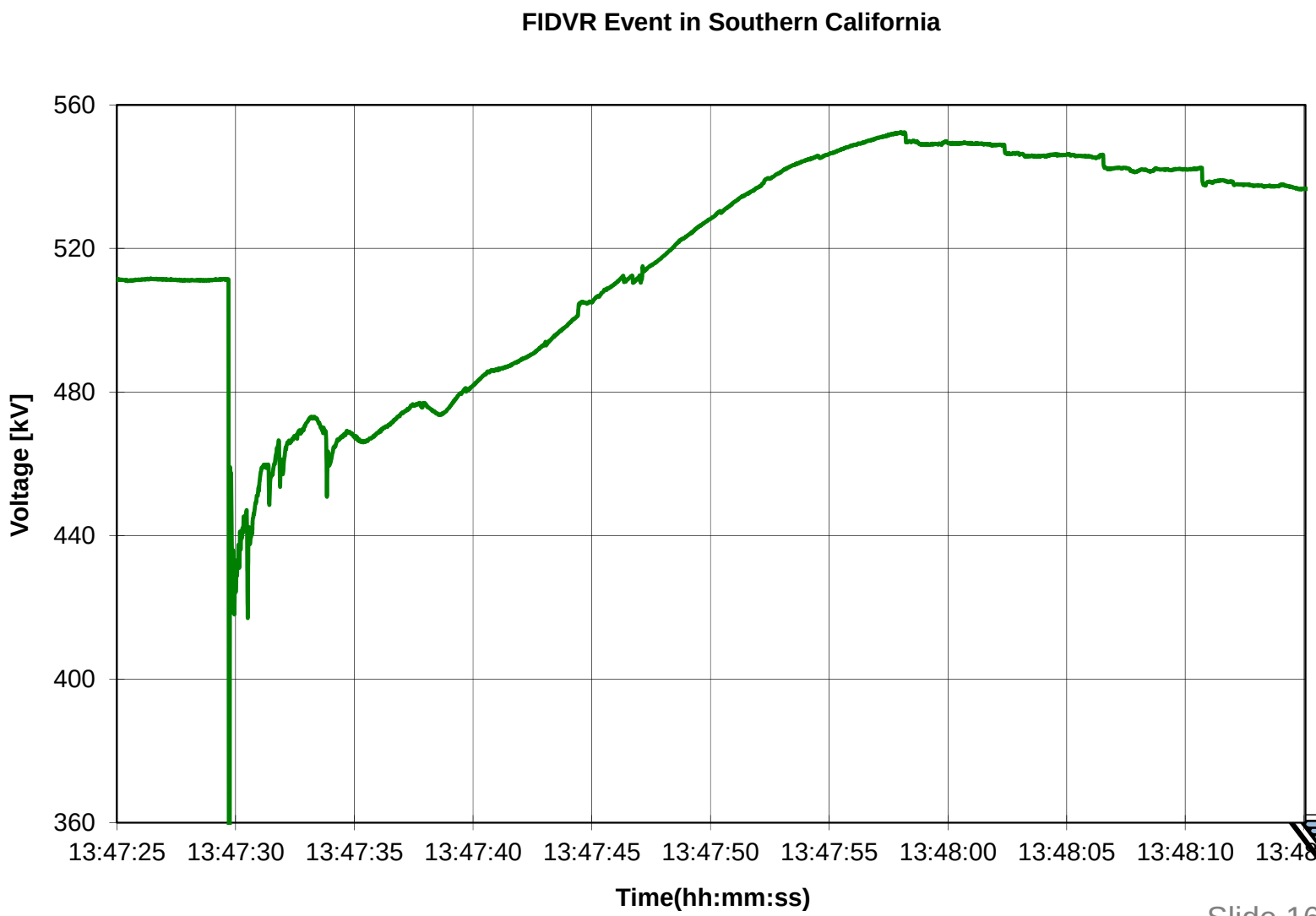
"Macro" Stability Issues



"Macro" Stability Issues



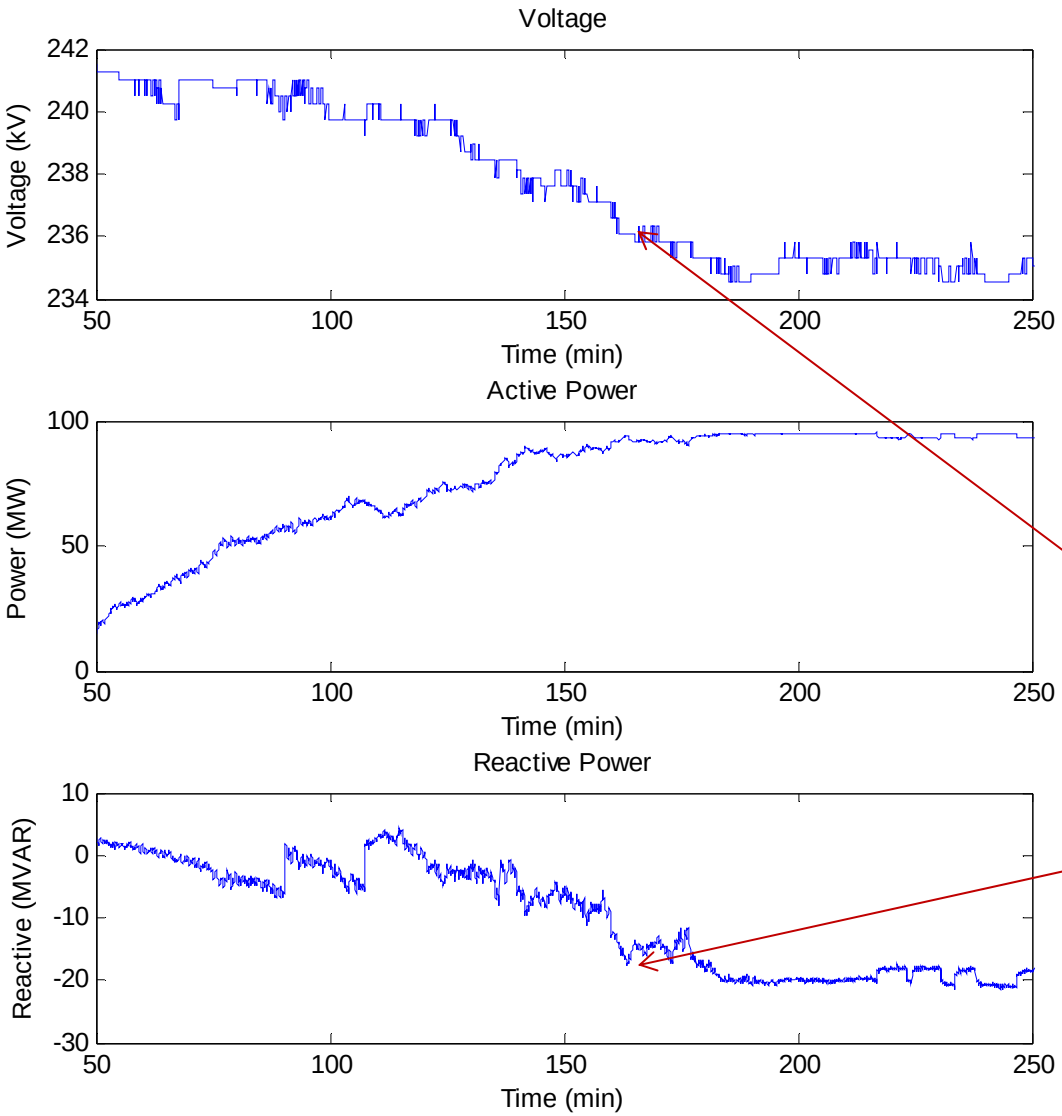
"Macro" Stability Issues



2006 Study…

- How integrating 3,000 MW of wind generation will impact the system "macro" stability
- Conclusion 1:
- The Interties will be de-rated if the wind power plants do not provide dynamic voltage control
  - Voltage stability
  - Damping of inter-area oscillations
  - Transient stability
- And we saw this happened at local scale
- …

Type 2 plant



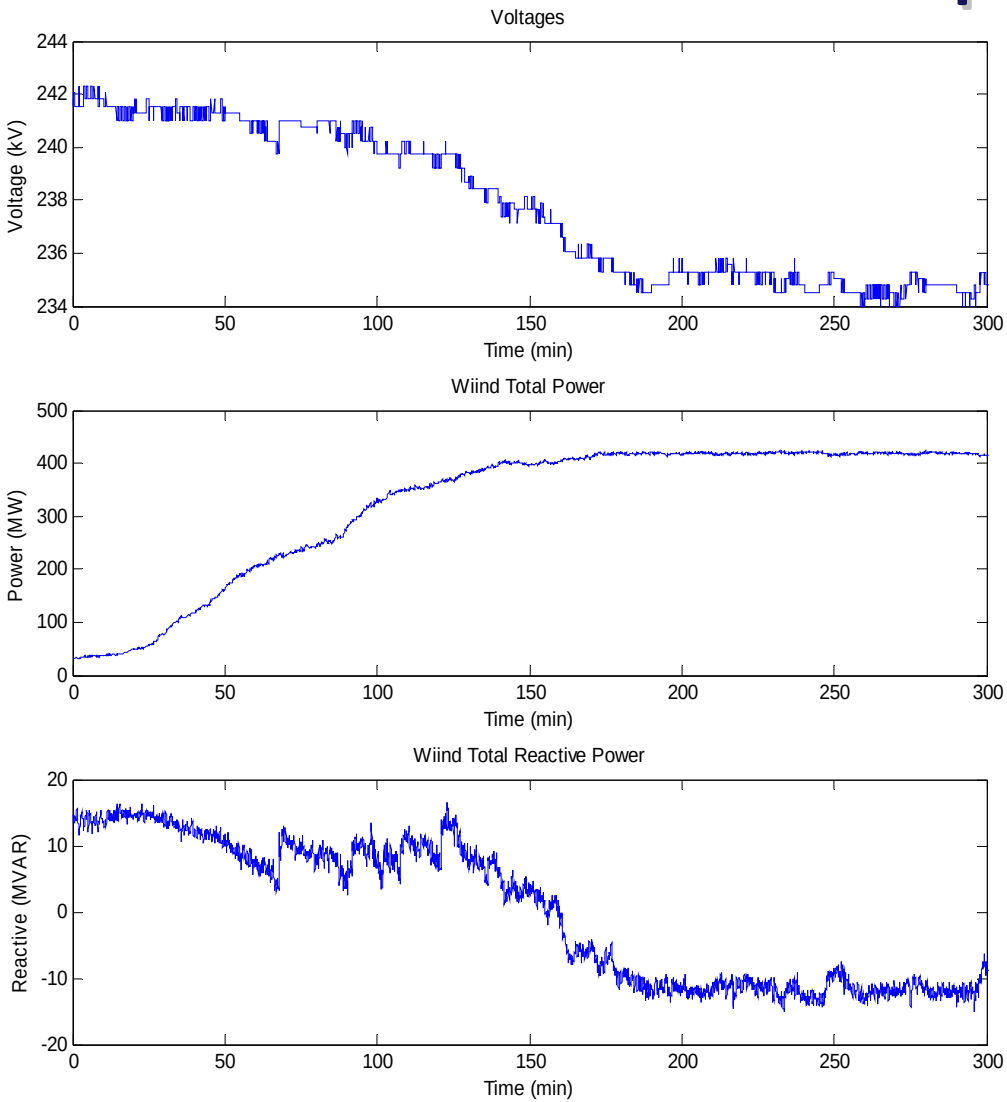
Early plants do not have STATCOMs and use only shunt caps

Operate mainly in power factor mode

As POI voltage declines …

WPP draws larger amount of reactive power

Wind Ramp Event



This is actual data, not simulations

Different plant

All lines in service

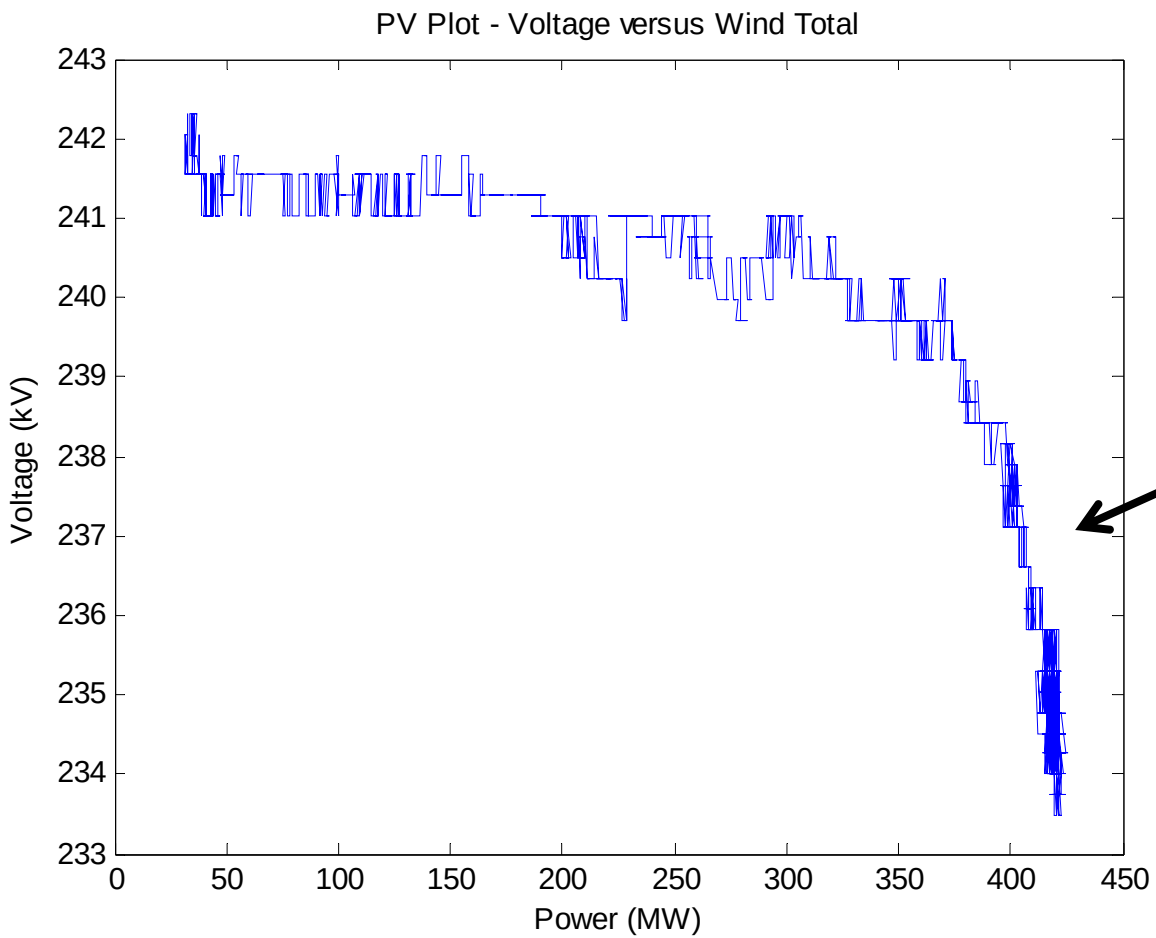
Wind ramping up event

Wind power plants are in **power factor** control mode

The issues have been addressed

Wind Ramp Event

PV-Curve for same event



The edge

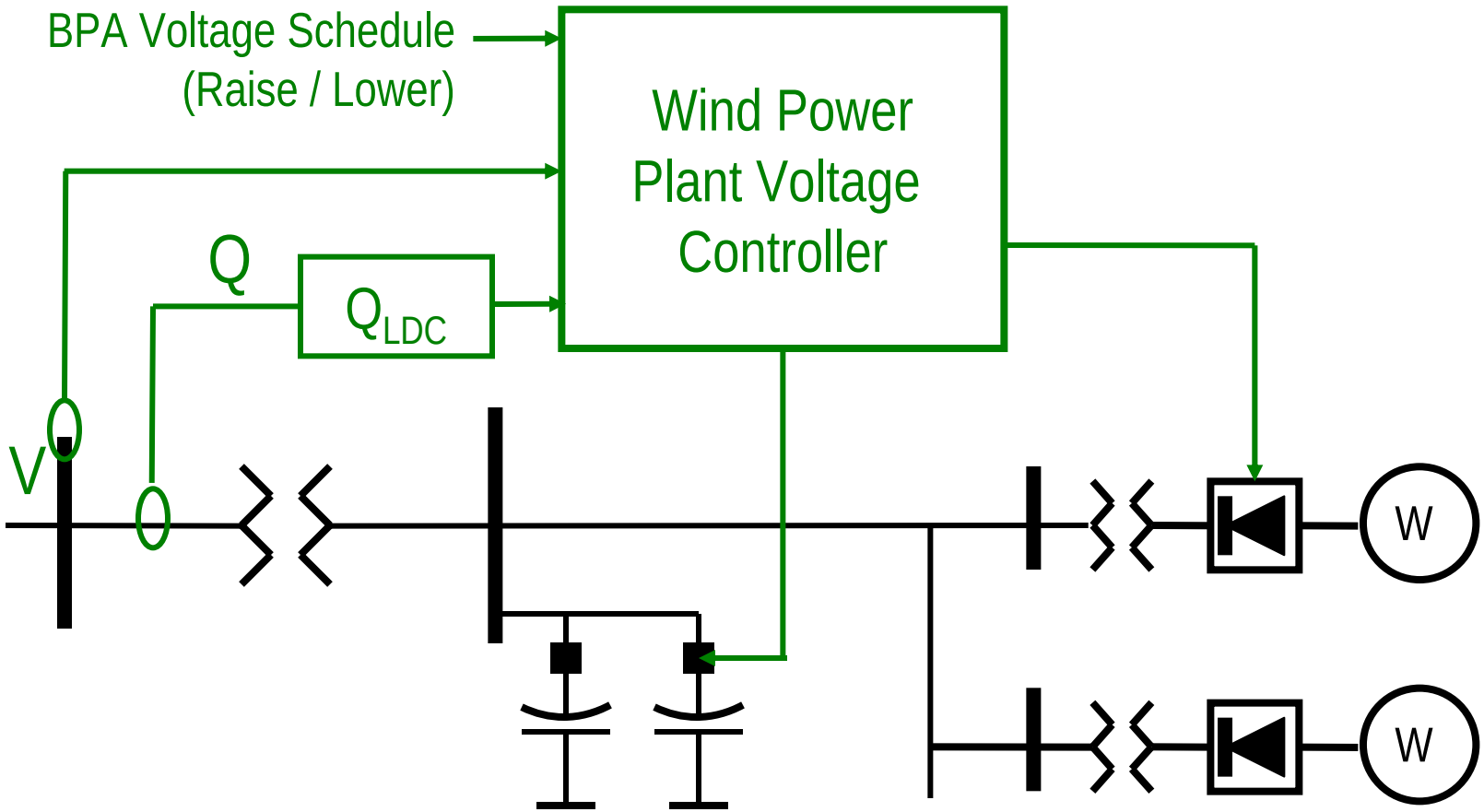
…2006 Study

- Conclusion 2:
- To integrate reliably 3,000 MW of wind
  - Wind power plants have adequate reactive capabilities
  - Wind power plants are operated in voltage control mode
- New wind generation technologies are capable of voltage control, and can offer performance better than synchronous machines.

Voltage Control Requirements

- BPA requires wind power plants to provide voltage control and reactive power to support the grid – just like other large generation projects
- How much reactive is needed:
  - Dynamic reactive sized to provide continuous +/- 0.95 power factor at 34.5-kV bus
  - Switched shunts to compensate for reactive power losses between WTGs and Point Of Interconnection, high switching duty
- How to control reactive resources:
  - Operate in continuous (no dead-band !) voltage control mode, control POI voltage to BPA schedule with reactive droop
  - Shunt switching to maximize the availability of dynamic capabilities at the plant

100 MW Type 3 or 4 Wind Generator Example

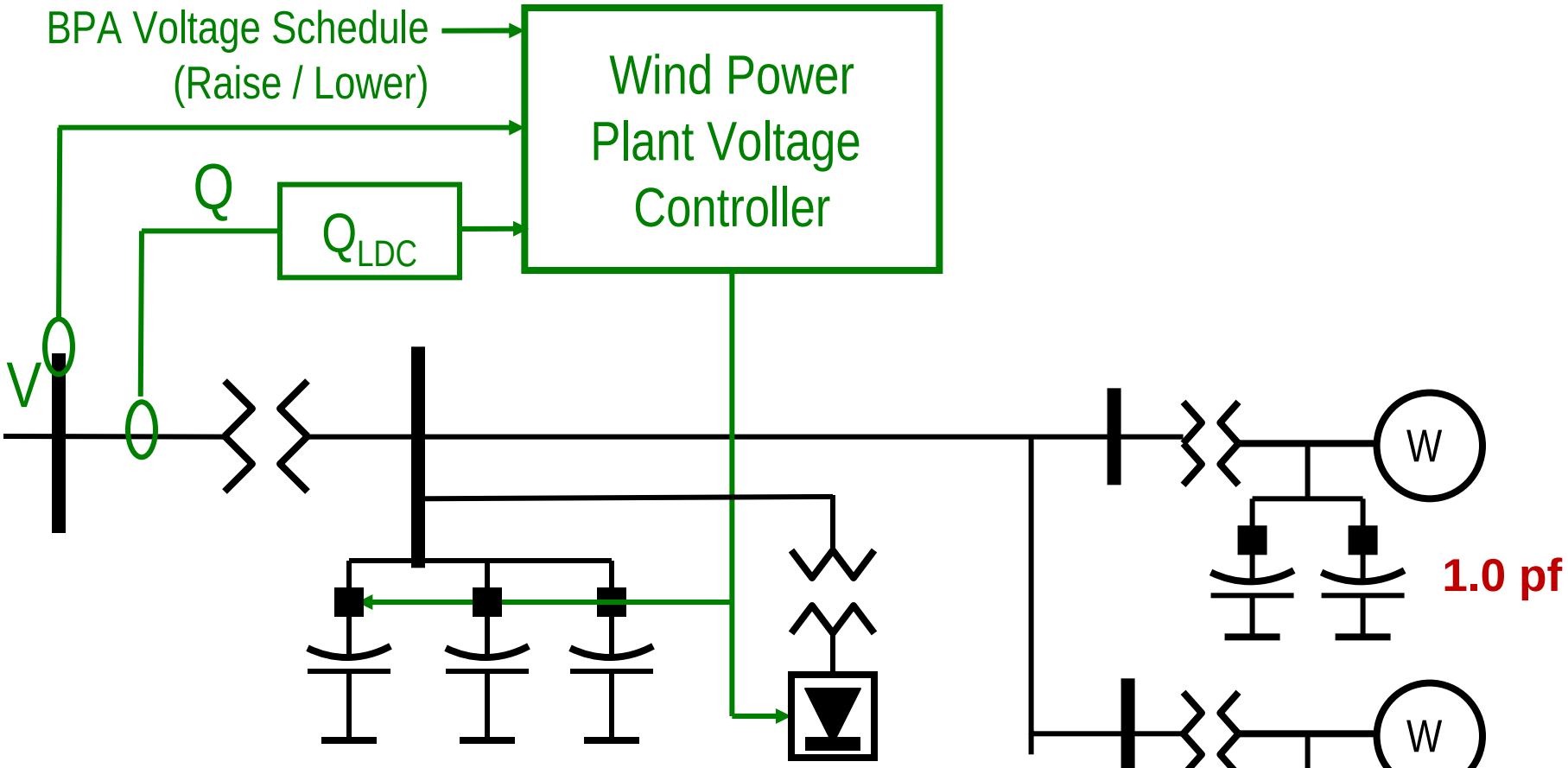


Two 9 MVAR switched shunts

capacitors to compensate for steady-state reactive losses, high switching duty
(can be on BPA HV bus for several plants)

+/- 0.95 pf (+/- 33 MVAR) continuously controllable

100 MW Type 2 with STATCOM



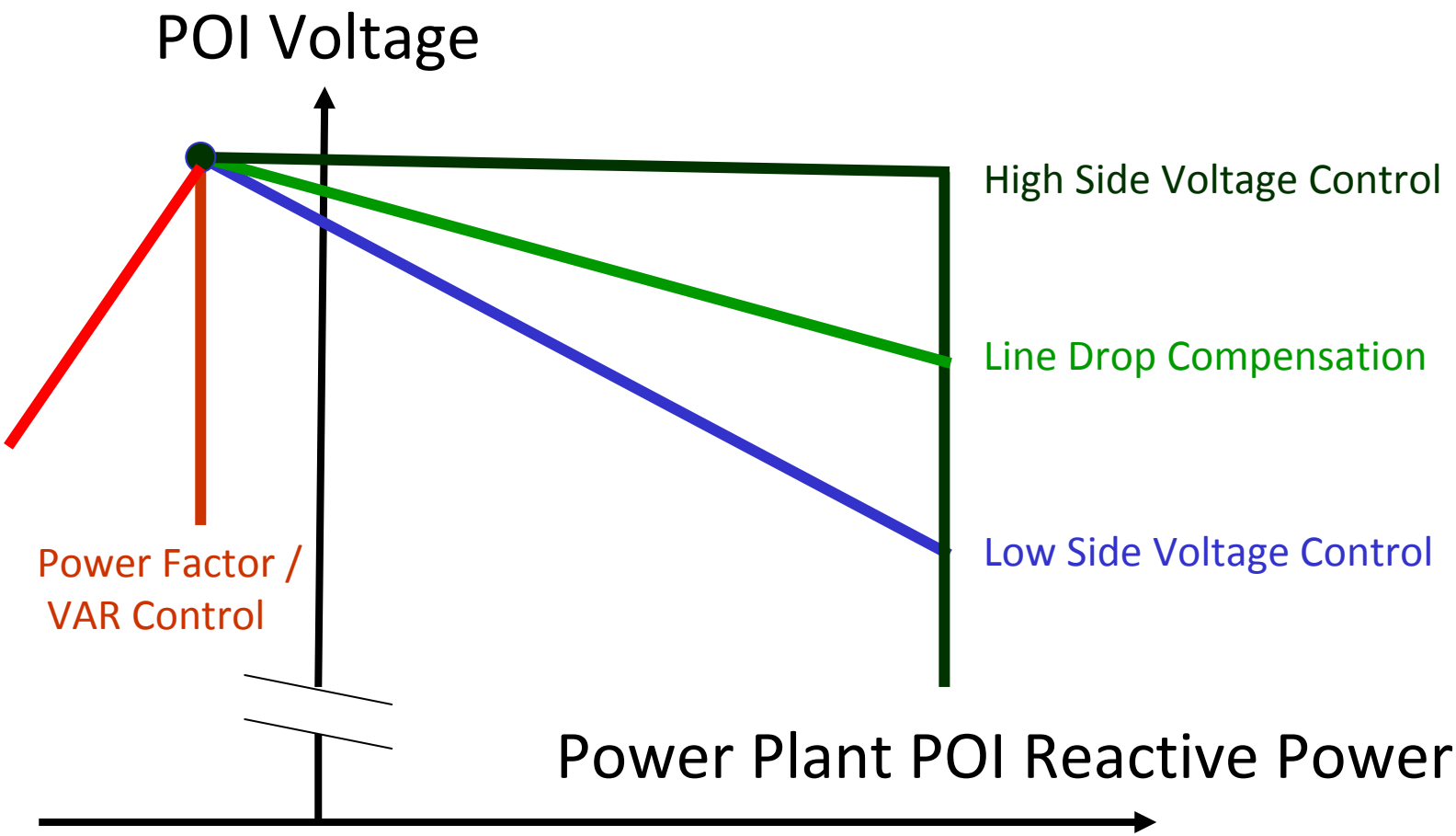
Three 10 MVAR switched shunts

capacitors to compensate for steady-state reactive losses, high switching duty (can be on BPA high side)

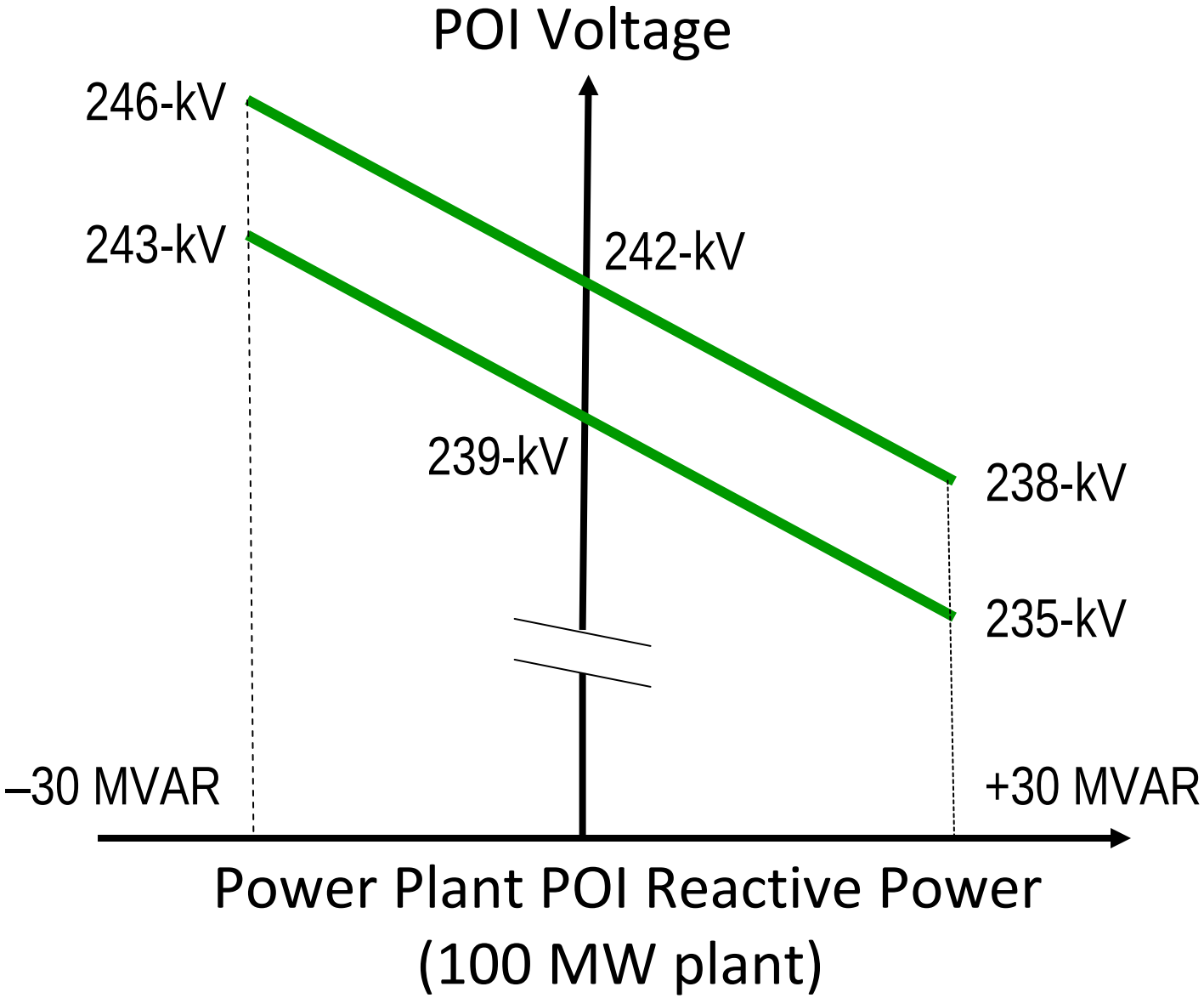
+/- 16 MVAR STATCOM

+/-32 MVAR 2-second overload capability

Voltage Control

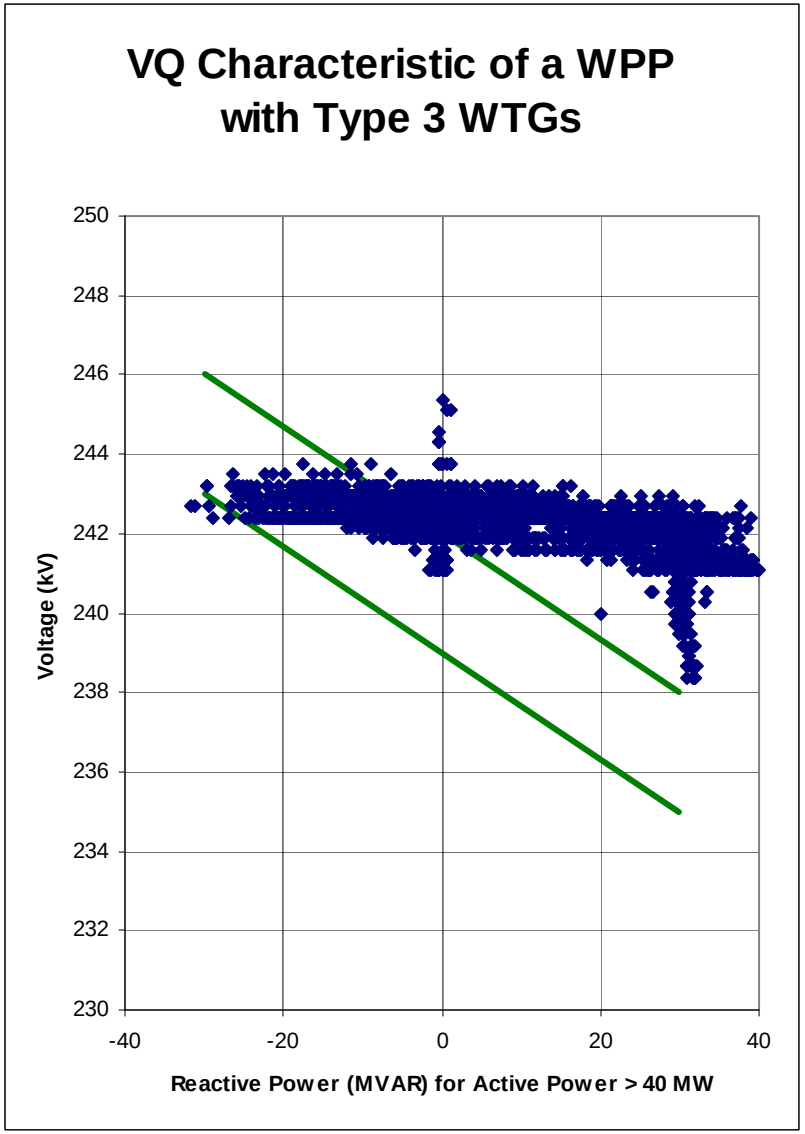


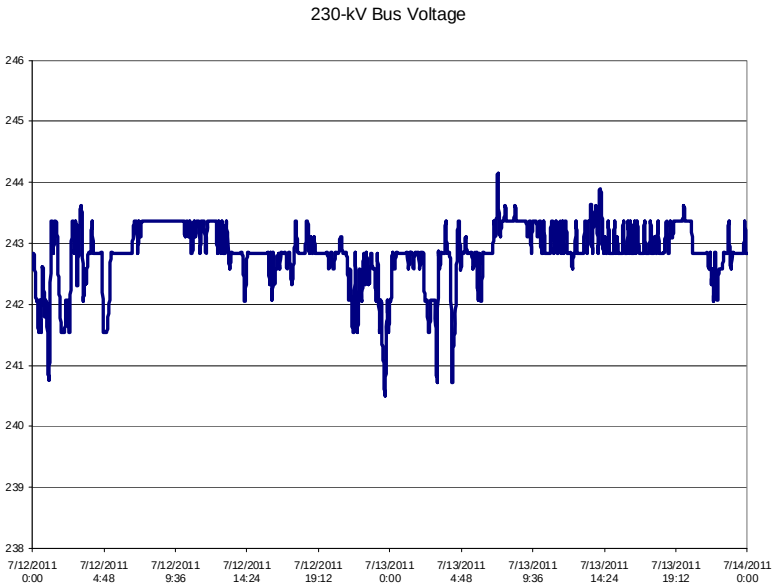
Voltage Control

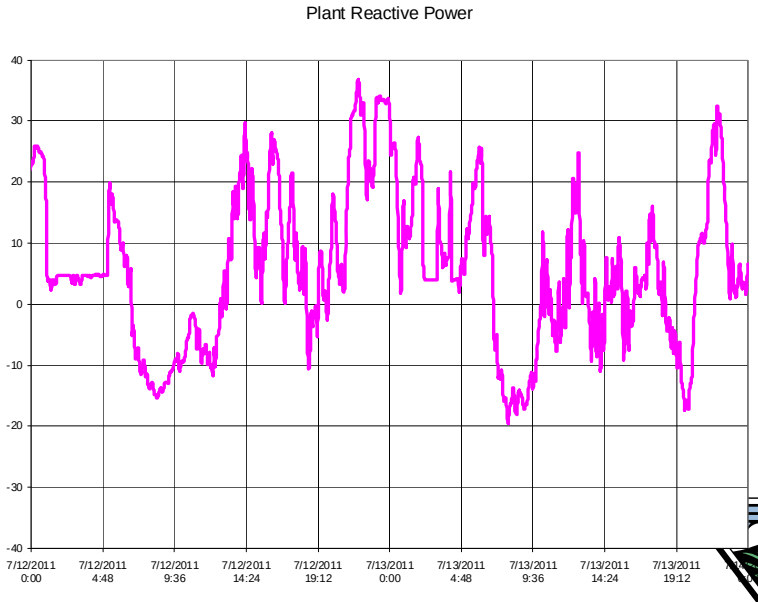


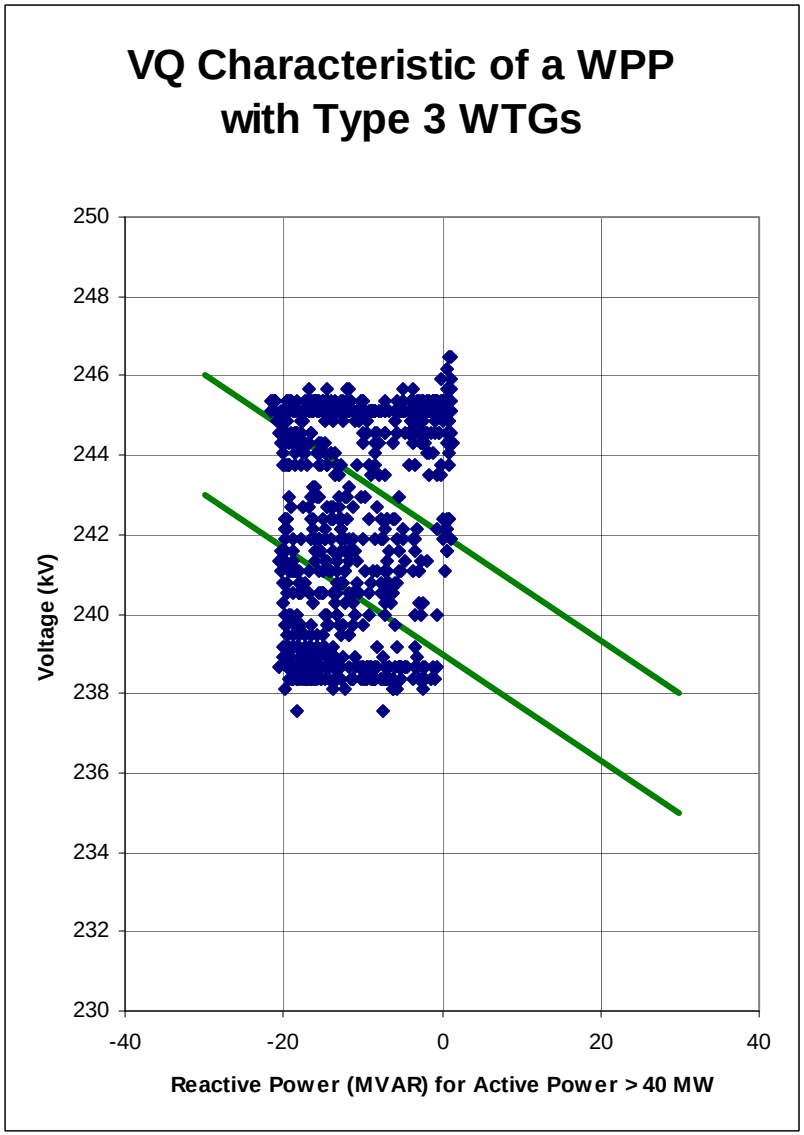
Observed Challenges

- A plant is commissioned in high side voltage control
- Plant experiences large MVAR swings for small voltage fluctuations
- Power plant operator turns plant into MVAR control
- BPA contacts plant operator, eventually the plant is set to a “hybrid” mode – MVAR controller with voltage over-ride


VQ Characteristic of a WPP with Type 3 WTGs
Voltage (kV)
250
248
246
244
242
240
238
236
234
232
230
-40
-20
0
20
40
Reactive Power (MVAR) for Active Power > 40 MW


230-kV Bus Voltage
246
245
244
243
242
241
240
239
238
7/12/2011 0:00
7/12/2011 4:48
7/12/2011 9:36
7/12/2011 14:24
7/12/2011 19:12
7/13/2011 0:00
7/13/2011 4:48
7/13/2011 9:36
7/13/2011 14:24
7/13/2011 19:12
7/14/2011 0:00


Plant Reactive Power
40
30
20
10
0
-10
-20
-30
-40
7/12/2011 0:00
7/12/2011 4:48
7/12/2011 9:36
7/12/2011 14:24
7/12/2011 19:12
7/13/2011 0:00
7/13/2011 4:48
7/13/2011 9:36
7/13/2011 14:24
7/13/2011 19:12


VQ Characteristic of a WPP
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Voltage (kV)
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238
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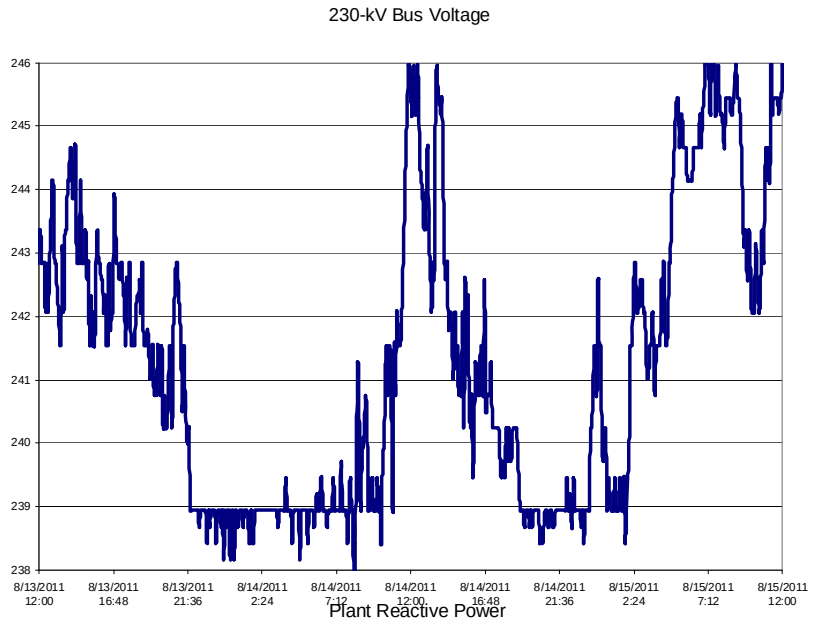
-40
-20
0
20
40
Reactive Power (MVAR) for Active Power > 40 MW


230-kV Bus Voltage
246
245
244
243
242
241
240
239
238
8/13/2011 12:00
8/13/2011 16:48
8/13/2011 21:36
8/14/2011 2:24
8/14/2011 7:12
8/14/2011 12:00
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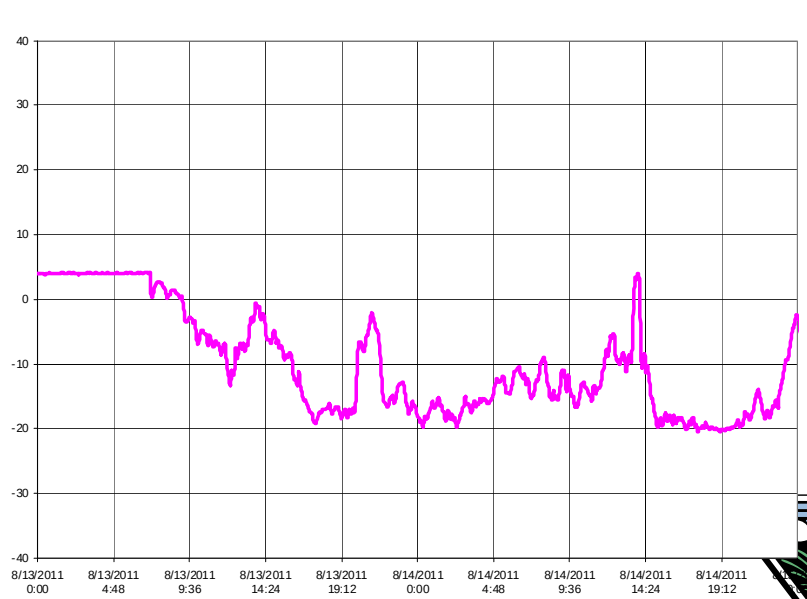
8/15/2011 7:12
8/15/2011 12:00


Plant Reactive Power
40
30
20
10
0
-10
-20
-30
-40
8/13/2011 0:00
8/13/2011 4:48
8/13/2011 9:36
8/13/2011 14:24
8/13/2011 19:12
8/14/2011 0:00
8/14/2011 4:48
8/14/2011 9:36
8/14/2011 14:24
8/14/2011 19:12

Observed Challenges

- Reactive power deliverability
- Voltage control dead-bands
- Coordination of dynamic reactive and shunt capacitor switching within a plant
- Shunt capacitor availability

- How to test the voltage control response ?

2011 Study

- How integrating 8,000 MW of wind generation will impact the system “macro” stability
- Studies done up to now has not shown “macro” stability issues with 8,000 MW of wind in Pacific Northwest (as long as wind power plants are in agreements with BPA voltage control requirements and study models are correct)
- … Will reality agree with the studies ?