

# Frequency Response Monitoring in Western Interconnection

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CIGRE Grid of The Future Conference, October 2014, Houston, TX

# Outline

- Frequency Response
- Regulatory Landscape
- WECC Frequency Response Performance
- Frequency Response Analysis Tool
- Conclusions and Future Work

# Frequency Response

FERC defines in RM13-11:

*“Frequency response* is a measure of an Interconnection’s ability to stabilize frequency immediately following the sudden loss of generation or load, and is a *critical component of the reliable operation* of the Bulk-Power System, particularly during disturbances and recoveries.”

# Regulatory Landscape - West

- WECC had several attempts to develop a regional frequency-responsive reserve standard from 1999 to 2010, driven by
  - frequency response imbalances in the West (hydro-based North vs. thermal-based South)
  - needing to determine reliability-justified frequency responsive reserves following California energy crisis
- WECC developed and approved White Paper on Frequency Responsive Reserve Standard in 2004
- FRR criterion was voted down in 2009

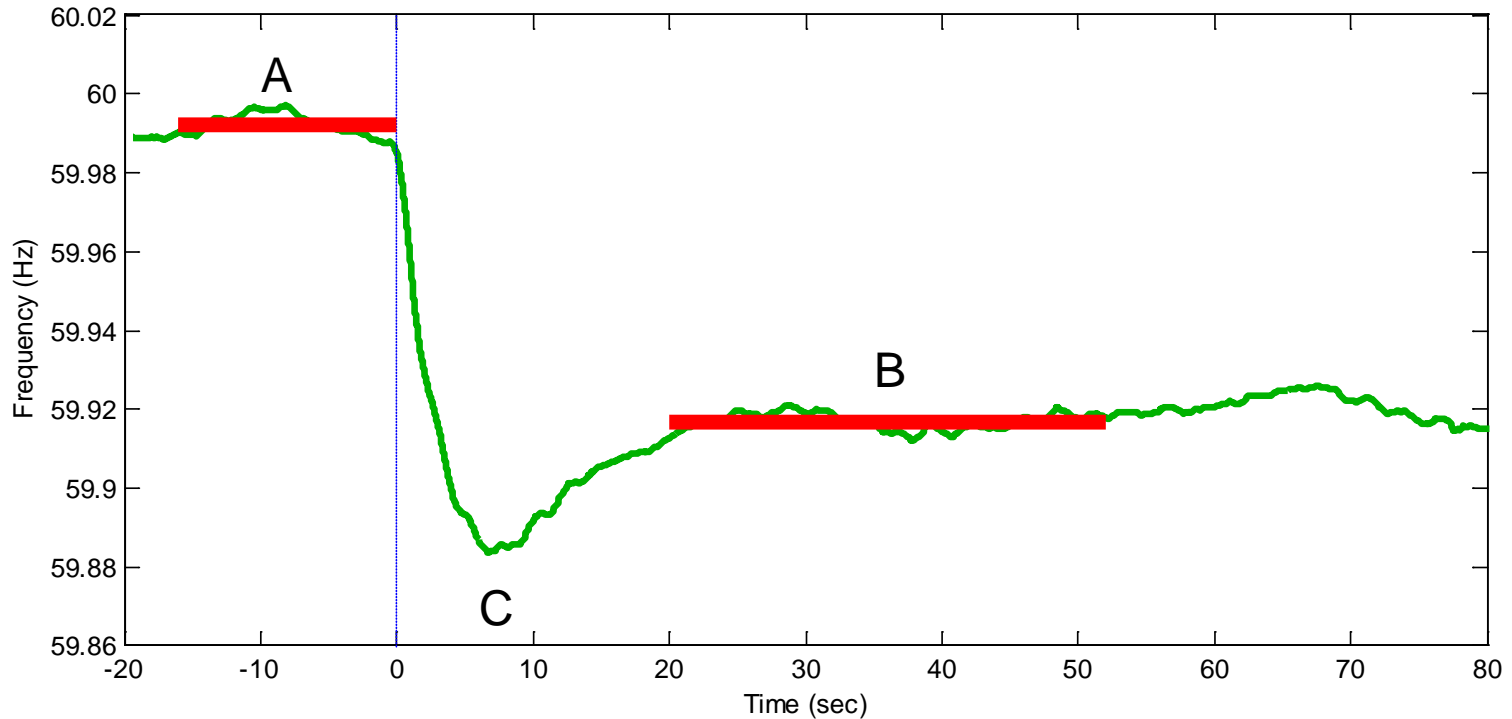
# Regulatory Landscape - National

- FERC-commissioned report on Frequency Response Metrics, 2010
- FERC held Technical Conferences, 2010
- NERC Frequency Response Initiative, 2011-2012
- NERC BAL-003-1 Frequency Response and Frequency Response Bias Reliability Standards is approved in 2013
  - Simplicity is the major advantage, as well as a major limitation

# NERC BAL-003-1

- Design Event for WECC is N-2 (Palo Verde outage) not to result in UFLS (starting at 59.5 Hz in the West)
- Interconnection Frequency Response Obligation (IFRO) is about 950 MW per 0.1 Hz at settling frequency (point B)
- IFRO is prorated among Balancing Authorities (BAs) based on annual load and generation
- BAs are responsible for providing frequency response,
  - BA FRM is measured as change in BA interchange over the delta frequency between initial and settling values
- Formation of Reserve Sharing Groups is permitted

# Frequency Response Measure

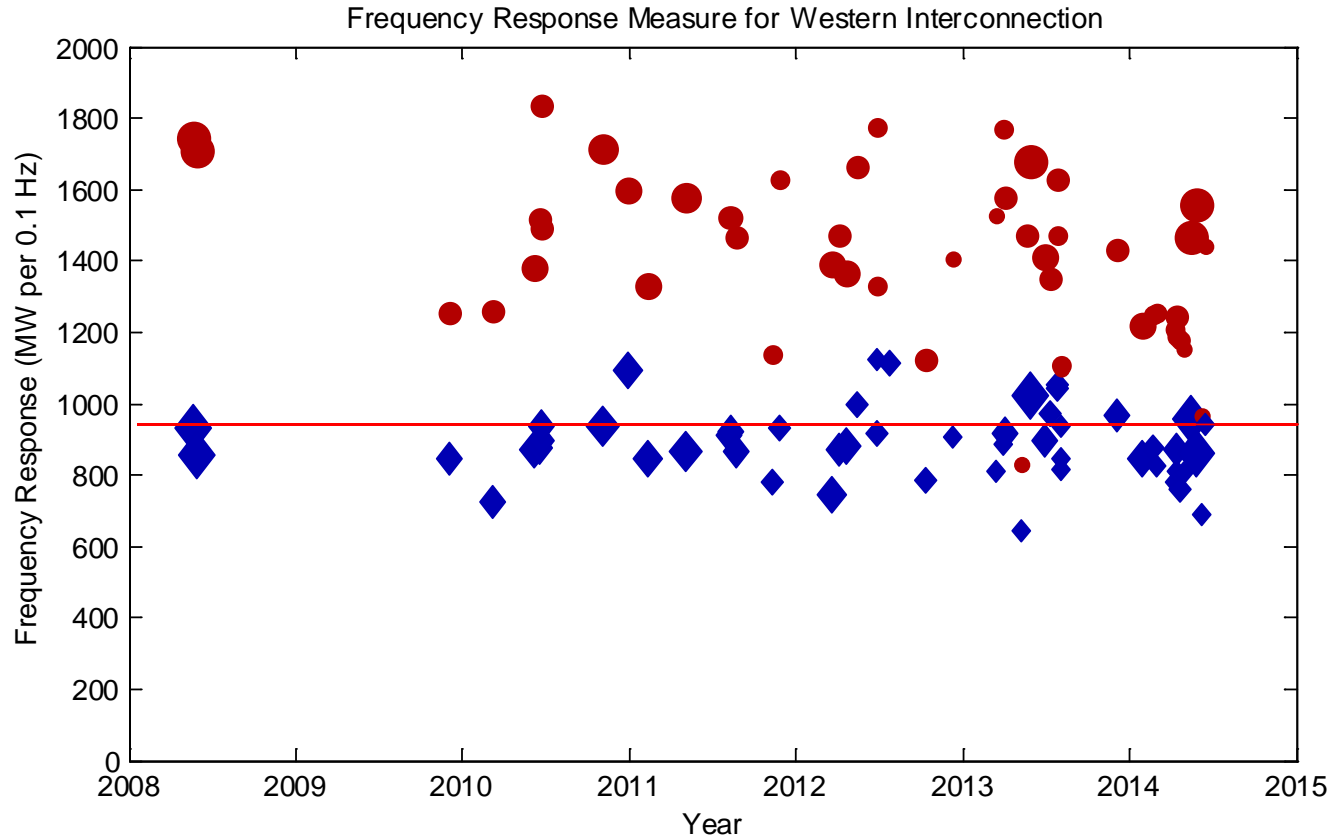


**NERC FRM BAL-003-1: Frequency difference between Point A and Point B**

LBNL Metrics: Frequency difference between Point A and Point C

# Western Interconnection Performance

WECC IFRO  $\sim 950$  MW per 0.1 Hz, WECC IFRM is trending  $\sim 1,400$  to  $1,600$  MW per 0.1 Hz  
Response at nadir: required  $\sim 580$  MW per 0.1 Hz, actual is about  $800$  MW per 0.1 Hz

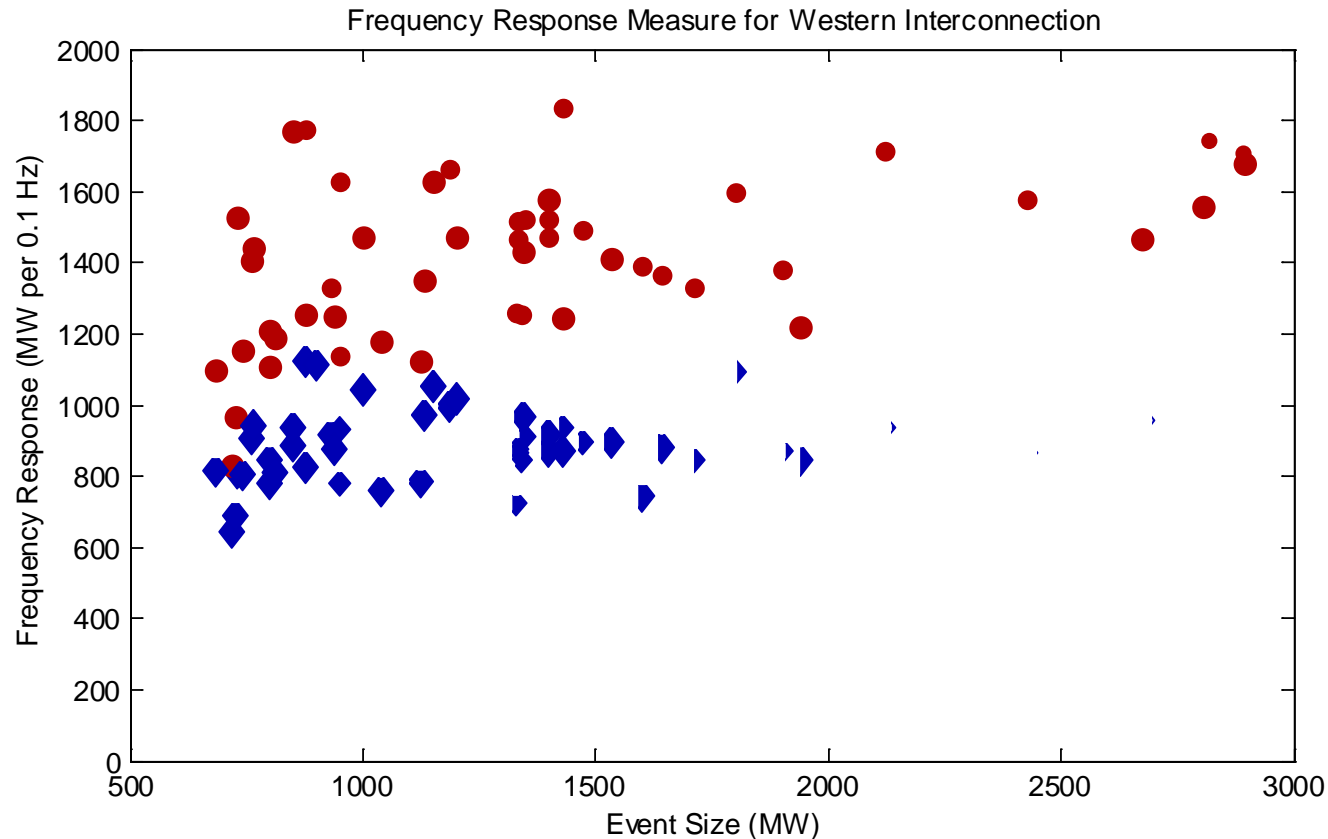


- Red dots – frequency response measured at point B (settling) using NERC FRM methodology
- Blue diamonds – frequency response is measured at point C (nadir)



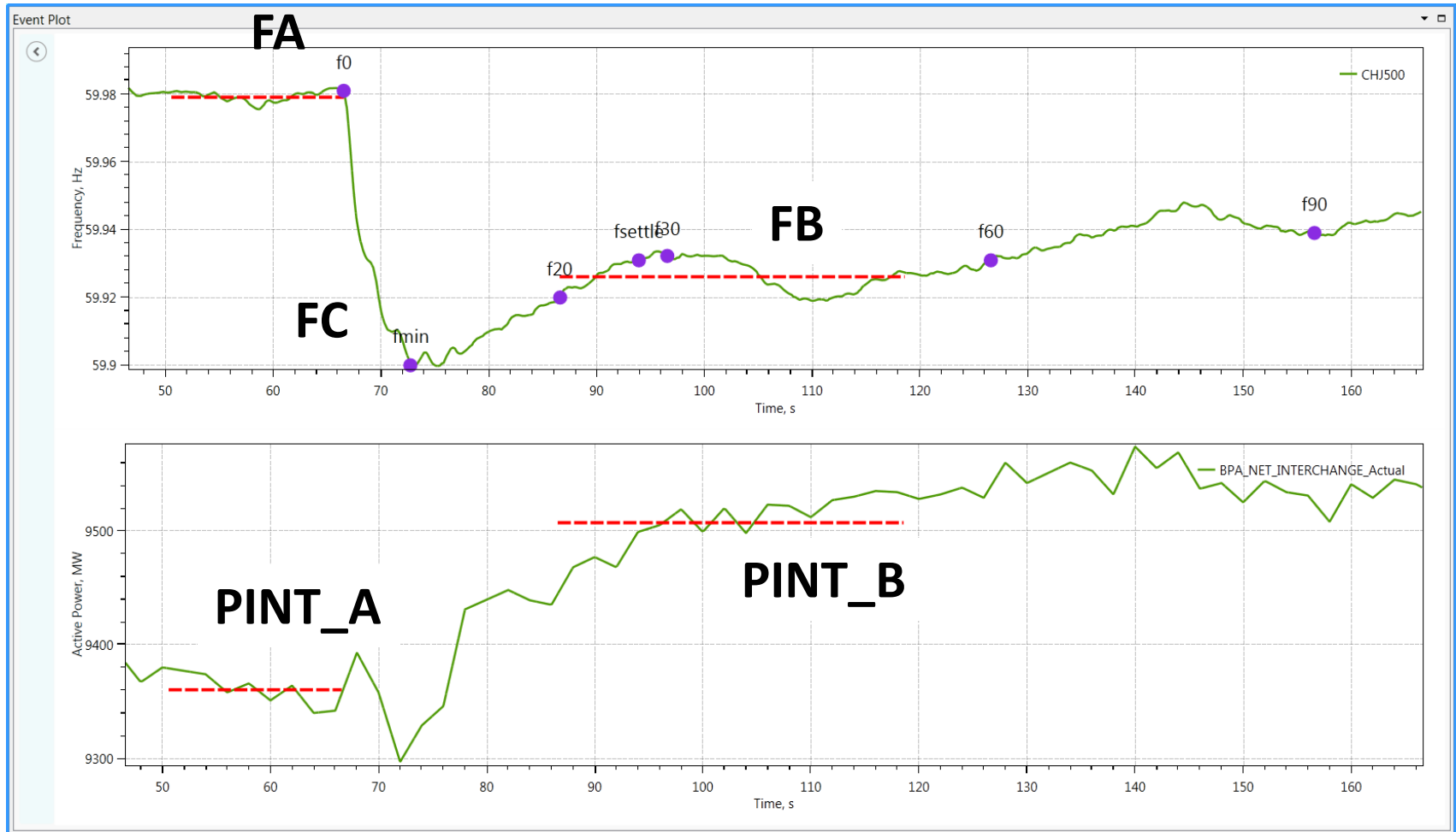
# Western Interconnection Performance

Response versus size of event: Small events do not extrapolate well to large  
Nadir measurement is more consistent, as it is driven by system physics



- Red dots – frequency response measured at point B (settling) using NERC FRM methodology
- Blue diamonds – frequency response is measured at point C (nadir)

# BA Frequency Response Measure Calculation



$$BA\ FRM = (PINT\_B - PINT\_A + BA\ GEN\ LOSS) / (FA - FB)$$

# Frequency Response Analysis Tool

WECC JSIS, NASPI, BPA, CERTS and PNNL collaborate in the common goal to deliver applications to the industry for frequency response analysis at the interconnection, Balancing Authority and individual power plant levels.

- Develop and deploy applications for interconnection-wide frequency response analysis,
- Develop and deploy applications that enable Balancing Authorities to calculate Frequency Response Measure per NERC BAL-003-1 from synchrophasor and SCADA data,
- Baseline historic frequency response performance for an interconnection, Balancing Authorities, and power plants,
- Develop and deploy applications for monitoring and validation of frequency response of power plants to help a Balancing Authority to determine its inventory of frequency-responsive resources,
- Baseline power pick-up on major transmission paths due to frequency response, and.

# Frequency Response Analysis Tool

- **Frequency response monitoring**
  - **Interconnection**
    - **Balancing Authority**
      - Power Plant
- Power pick-up on major transmission paths

# Database of Events

# Add / View / Edit Events



Frequency Response Tool

Event Name	Date	Time	Disturbance	FRM NERC	FRM B/
Comanche U3	06/14/14	11:22:00	765	1443.396	277.004
Four Corners Unit 4 - 2104B	06/06/14	03:37:00	725	966.667	265.753
PDCI RAS 2014A	05/26/14	17:31	2806	1558.889	325.298
NW RAS + Kemano + Sprinerville	05/16/14	23:18	2673	1468.681	365.893
Intermountain IPP Unit 1	04/29/14	5:23:00	740	1156.25	311.887
PNW RAS - Low Gen.Drop	04/21/14	10:41:00	1039	1180.682	746.58
Colstrip	04/15/14	5:46:00	810	1191.176	278.46
NW RAS	04/15/14	14:43:00	1430	1247.4593	0
Four Corners Unit 4	04/09/14	17:33:00	800	1212.121	297.803
IPP Unit 1	02/27/14	8:54:00	877	1252.857	268.494
Intermountain Unit 2	02/21/14	10:14:00	938	1250.667	263.555
NW AC RAS + Springerville	01/29/14	6:47:00	2626	1377.581	0
NW AC RAS	01/29/14	7:03:00	1940	1221.4086	0
Palo Verde Unit 2 Outage	12/02/13	16:59:00	1344	1429.787	312.598
Comanche 3	08/04/13	0:59:00	682	1100.1749	0
Mica	08/03/13	2:51:00	800	1110.0315	0
Mica	08/03/13	20:46:00	850	2263.7289	0
Grand Coulee 20 and 21	07/25/13	13:52:00	1000	1472.2583	0
Grand Coulee 20 and 21	07/25/13	10:50:00	1150	1630.1178	0
Diablo Canyon #2	07/10/13	9:50:00	1130	1350.9369	0
NW RAS	06/29/13	3:50:00	1534	1411.5335	0
PDCI RAS	05/30/13	15:59:00	2895	1678.0613	0
Grand Coulee 20 and 22	05/22/13	15:21:00	1200	1473.9372	0
Comanche	05/07/13	10:37:00	719	828.4502	0
NW RAS	04/01/13	8:08:00	1400	1579.5155	0
PNW	03/31/13	18:05:00	850	1770.9932	0
Comanche	03/14/13	17:14:00	730	1527.4759	0
PSCO	12/09/12	19:05:00	760	1407.8294	0
California ISO	10/11/12	12:09:00	1125	1124.8976	0
Four Corners	09/05/12	10:11:00	750	1061.941	0
BC Hydro	07/23/12	5:36:00	900	2812.3952	0
Arlington Valley and Palo Verde#1	07/04/12	7:20:40	1713	1586.0139	0
California ISO	06/28/12	8:40:40	877	1777.4293	0
PACE	06/25/12	9:30:00	929	1331.739	0
BCH and Boundary	05/14/12	19:02:00	1185	1663.1818	0
AC RAS	04/20/12	15:37:00	1643	1364.945	0

Event Characteristics

Event Description

Name: Intermountain IPP Unit 1

Date: 4/29/2014 Time: 5:23:00

Day: Tuesday

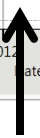
Disturbance Si: 740

Qualifying I:  Comments:

- Load/Generation
- Time/Frequency
- NERC Performance
- Additional Performance Indexes

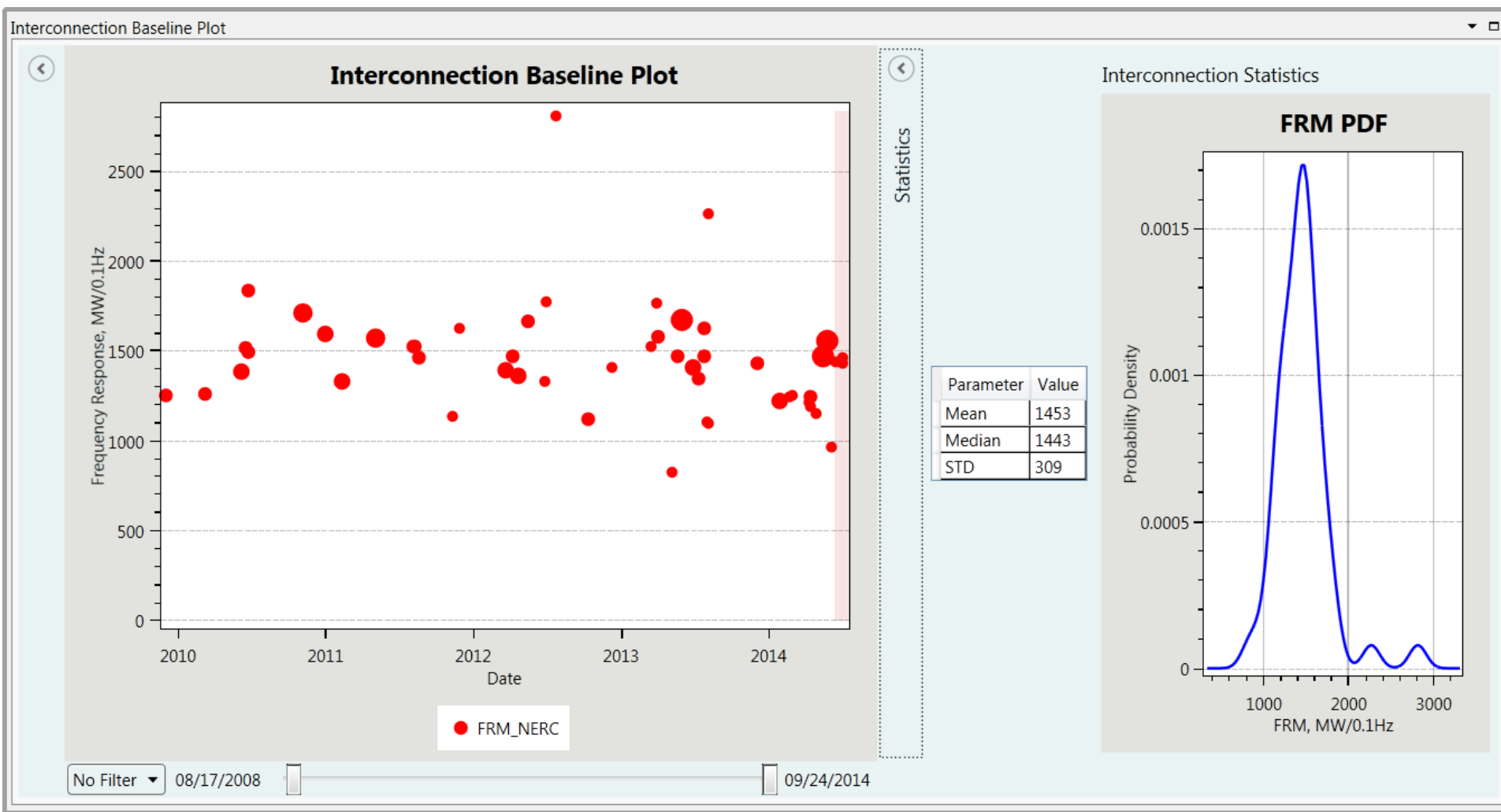
Event Plot

Baseline Plot

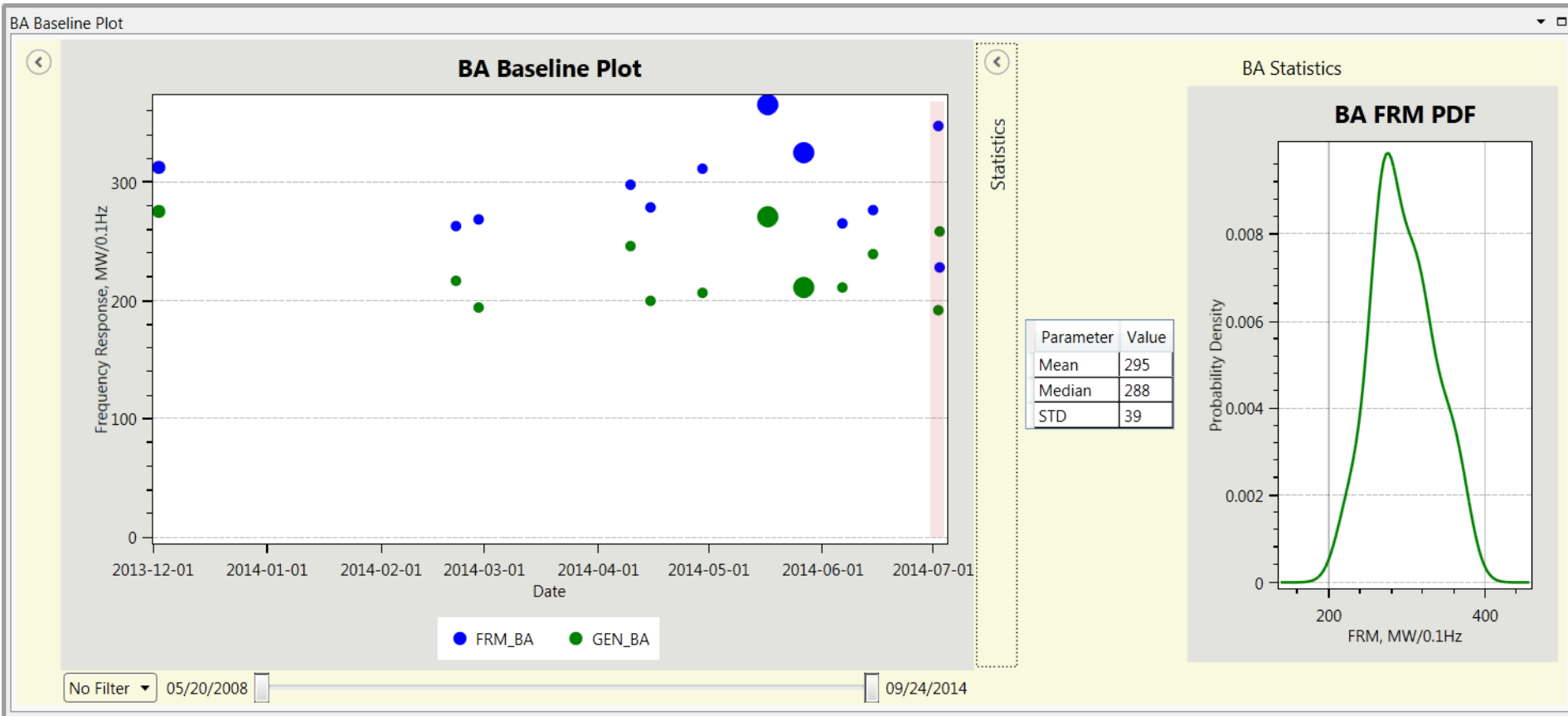


# Performance Baseline

# Western Interconnection Performance



# Balancing Authority Performance



Interchange response is measured for compliance with NERC BAL-003-1

Generation response is calculated to determine how much frequency response to acquire

# Power Plant Performance

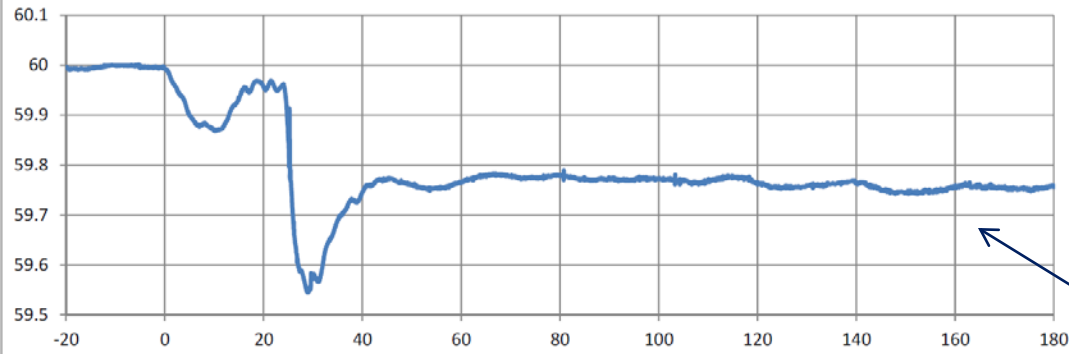
## Coming Soon



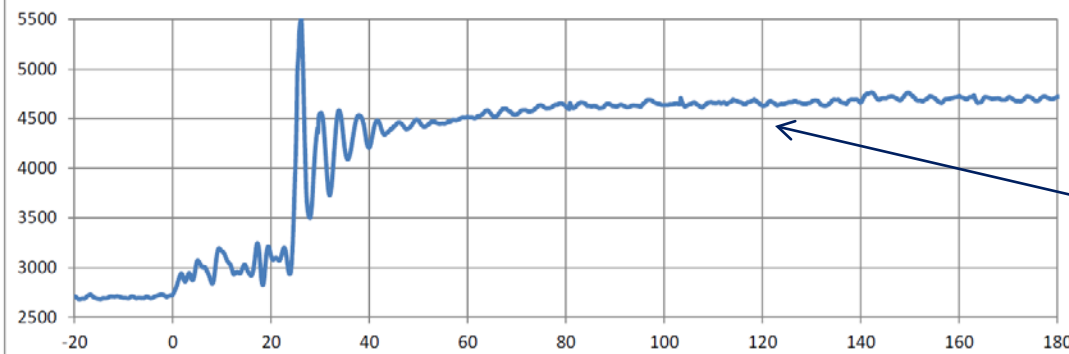


# Power Pick-Up on Transmission Paths

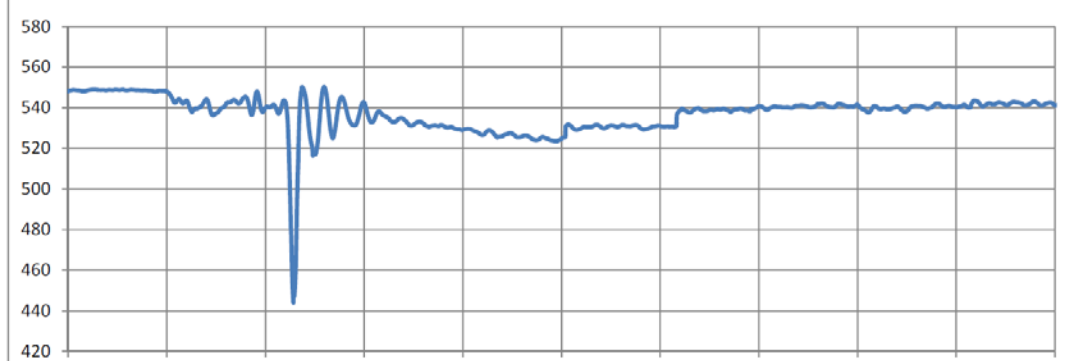
System Frequency



California - Oregon Intertie Active Power



Malin 500-kV Bus Voltage



Frequency is low

Path flow is above SOL

Time (sec)

# Need for Holistic View

## Governor:

- Frequency control
- Damping of power oscillation
- Voltage stability and thermal overloads due to governor response power pick-up
- Black-start



# Contact

- Tool web page: <https://svn.pnl.gov/FRTTool>
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- pavel.etingov@pnnl.gov