

# DOE/OE Transmission Reliability Program

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## Frequency Response Analysis Tool

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June 7-8, 2016

Washington, DC



# Project Objectives

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- Federal Energy Regulatory Commission (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.”*
- North American Electric Reliability Corporation (NERC) developed Frequency Response BAL-003-1 Standard, FERC approved the standard with effective date April 1<sup>st</sup> 2015.
- The frequency response measure (FRM) can be computed from the single event frequency response data (SEFRD).



# Project Objectives

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- The main objective of the project is to continue enhancements of the Frequency Response Analysis Tool (FRAT)
- FRAT application:
  - Released under an open source license
  - The tool calculates Frequency Response Measure (FRM) according to NERC BAL-003 standard.
  - The tool archives the historical events and baselines the system performance.
  - The tool automatically generates NERC Frequency Response Survey (FRS) reports
  - The tool has built in statistical analysis and advanced visualization capabilities



# Frequency Response Analysis Tool

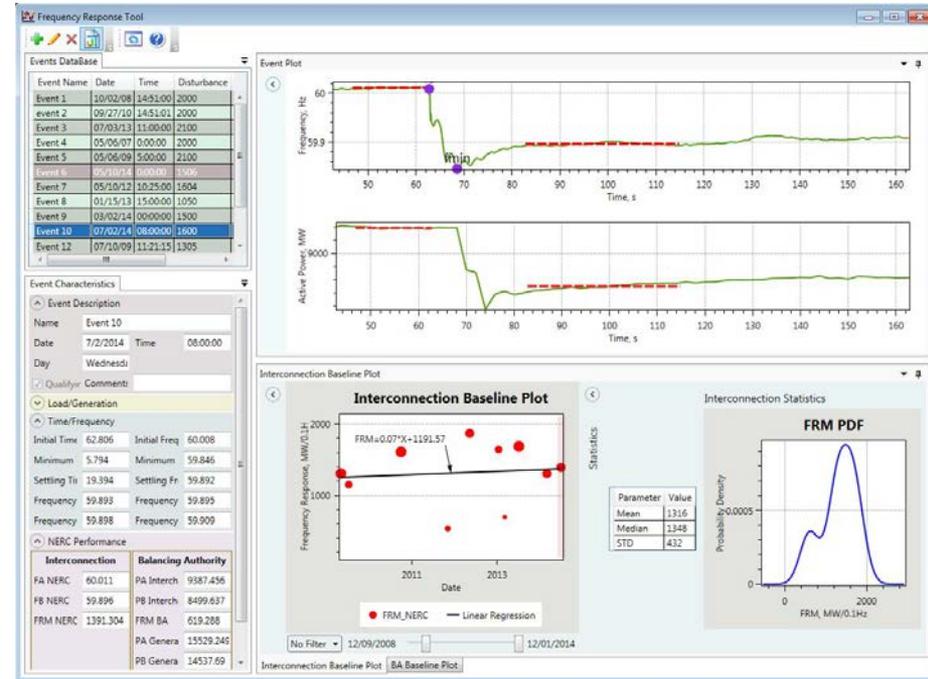
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- Developed under Bonneville Power Administration (BPA) and WECC JSIS technical guidance
- **Frequency response monitoring**
  - **Interconnection**
    - **Balancing Authority**
      - Power Plant
- Calculation NERC FRM using PMU and SCADA measurements
- Compliance reporting
- Baselining frequency response for interconnection and BA
- Supporting different data sources (csv, xml, OSIsoft PI, COMTRADE)
- Statistical Analysis



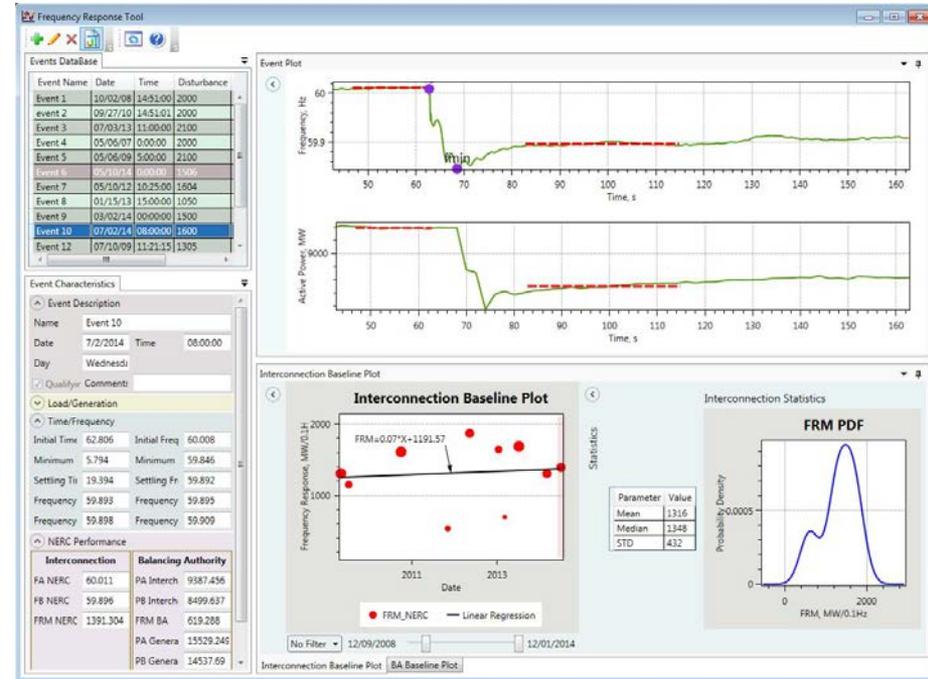
# Past major accomplishments

- FRAT (version 1.0) was released under an open source license in 2013
- FRAT (version 2.0) was released under an open source license in September 2014
- Received positive feedback from multiple industrial users including BPA, NERC, and WECC JSIS
- Development was funded by DOE and BPA



# FRAT 2.0

- Standalone Windows application
- New analytical functions including:
  - Calculation of the interconnection and balancing authority frequency response measure (FRM) according to the NERC BAL-003-01 Standard
  - Calculation of the power plant frequency response
  - Statistical analysis
- Redesigned user interface based on WPF framework
- Advanced visualization
- Automated reporting capabilities
- Support of different data sources



# Technical Accomplishments FY16

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- New version is expanded to national use;
- Multiple improvements based on NERC feedback
  - Time zones support
  - NERC BAL-003 and M4 events screening
  - Point C' calculation
- GUI improvements
- New reporting capabilities
- Connectivity to OSIsoft PI database.



# FRAT use at BPA

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- Bonneville Power Administration (BPA) is one of the early users of FRAT
- BPA provides feedback on the application development
- BPA uses frequency response baseline developed by FRAT for preparing its filings in response to FERC NOPR on BAL-003-1
- BPA uses the application for baselining its BA frequency response and determining the inventory of its frequency responsive reserves
- BPA uses the application to monitor the impact of renewable generation on its frequency response performance



# FRAT use at NERC

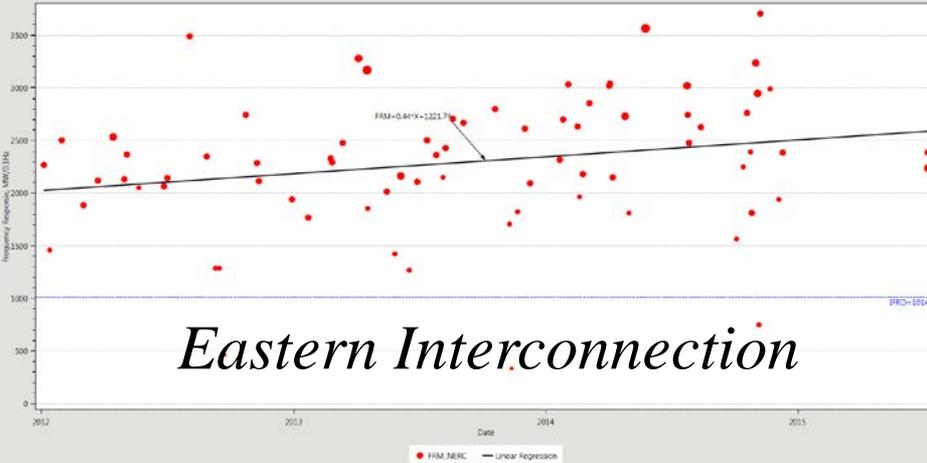
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- NERC worked closely with PNNL to make improvements to the FRAT for interconnection-wide frequency response analysis
- NERC using FRAT for event tracking for BAL-003-1 and ALR 1-12 (M4) events
- NERC using FRAT to generate the database of performance values for frequency response events for each of the four interconnections
- NERC using FRAT for determination of BAL-003-1 factors
  - Interconnection Frequency Response Obligation (IFRO)
  - Balancing Authority Frequency Response Obligations (BA FRO)



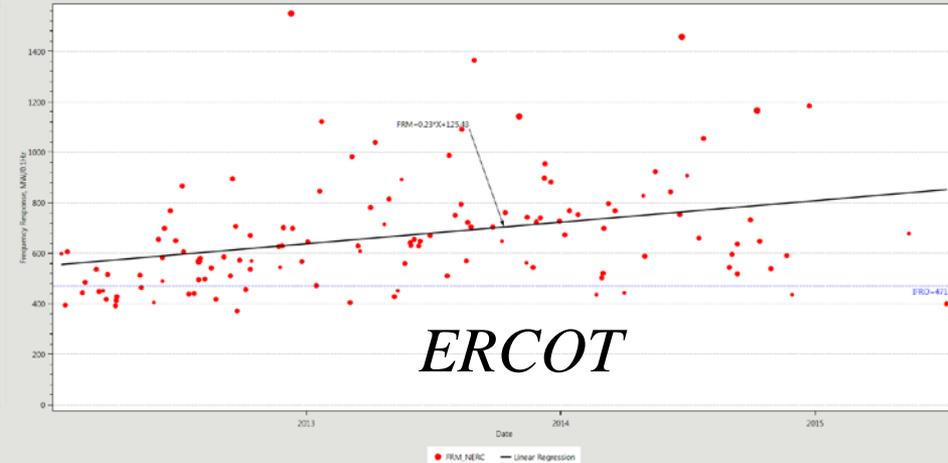
# FRAT use at NERC

Interconnection Baseline Plot



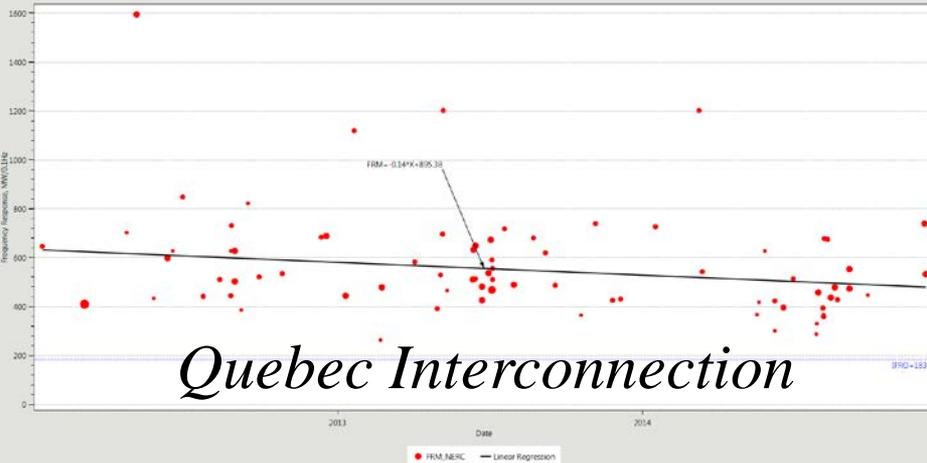
*Eastern Interconnection*

Interconnection Baseline Plot



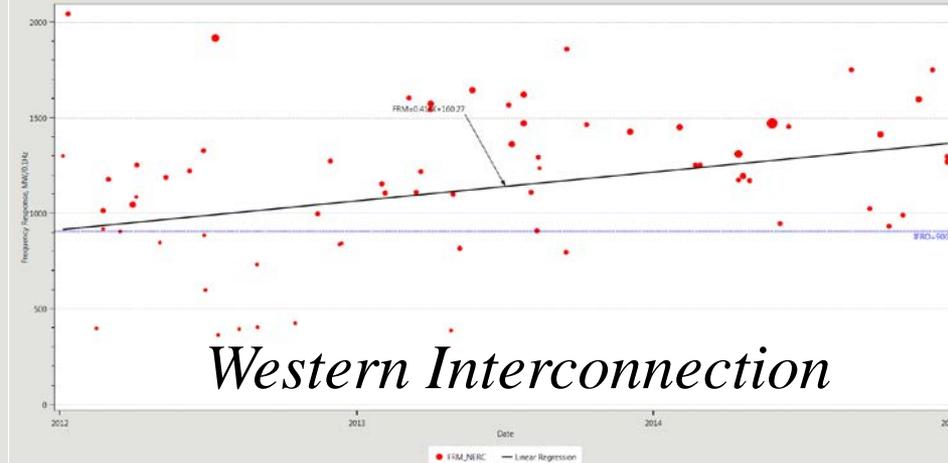
*ERCOT*

Interconnection Baseline Plot



*Quebec Interconnection*

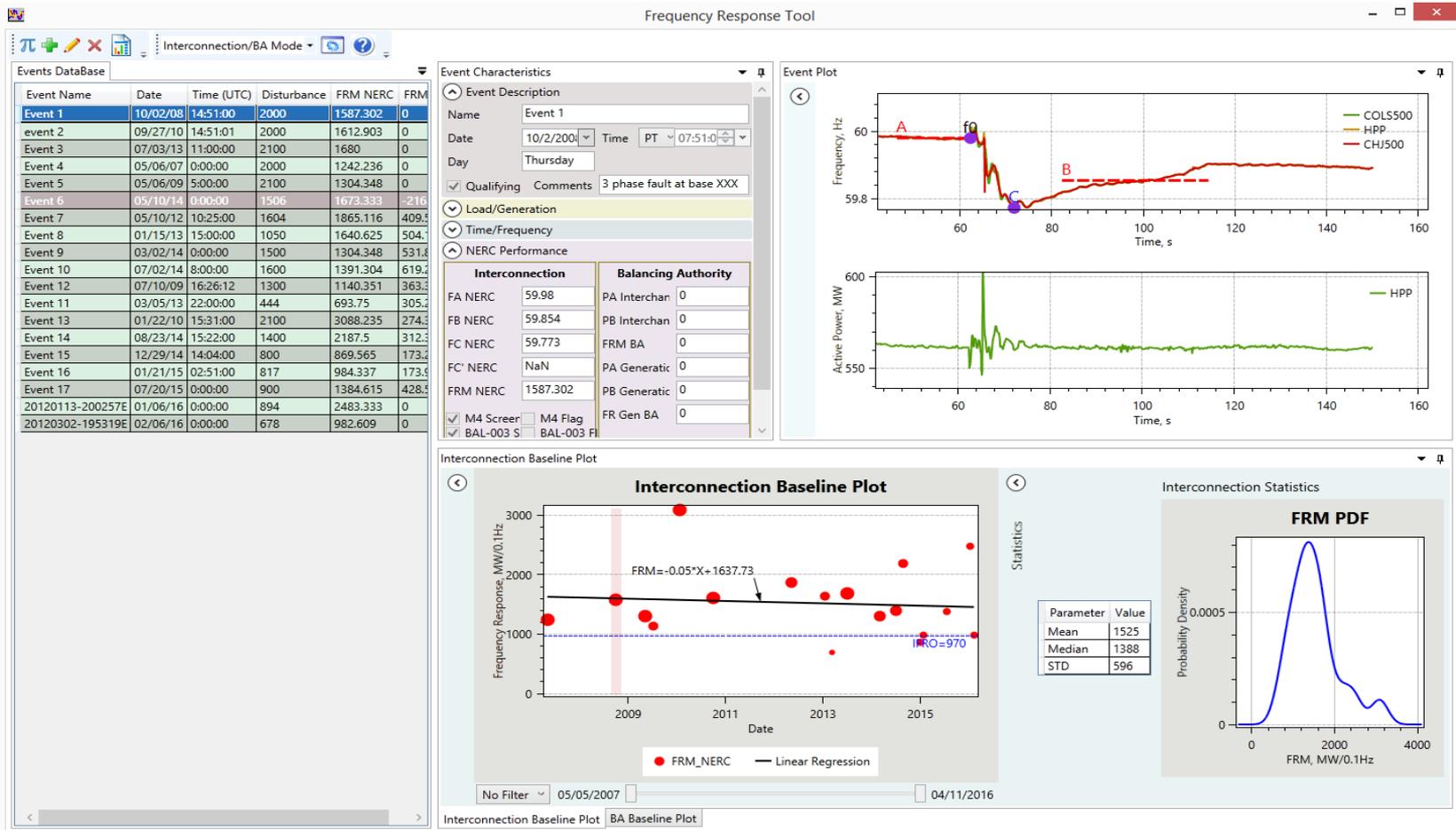
Interconnection Baseline Plot



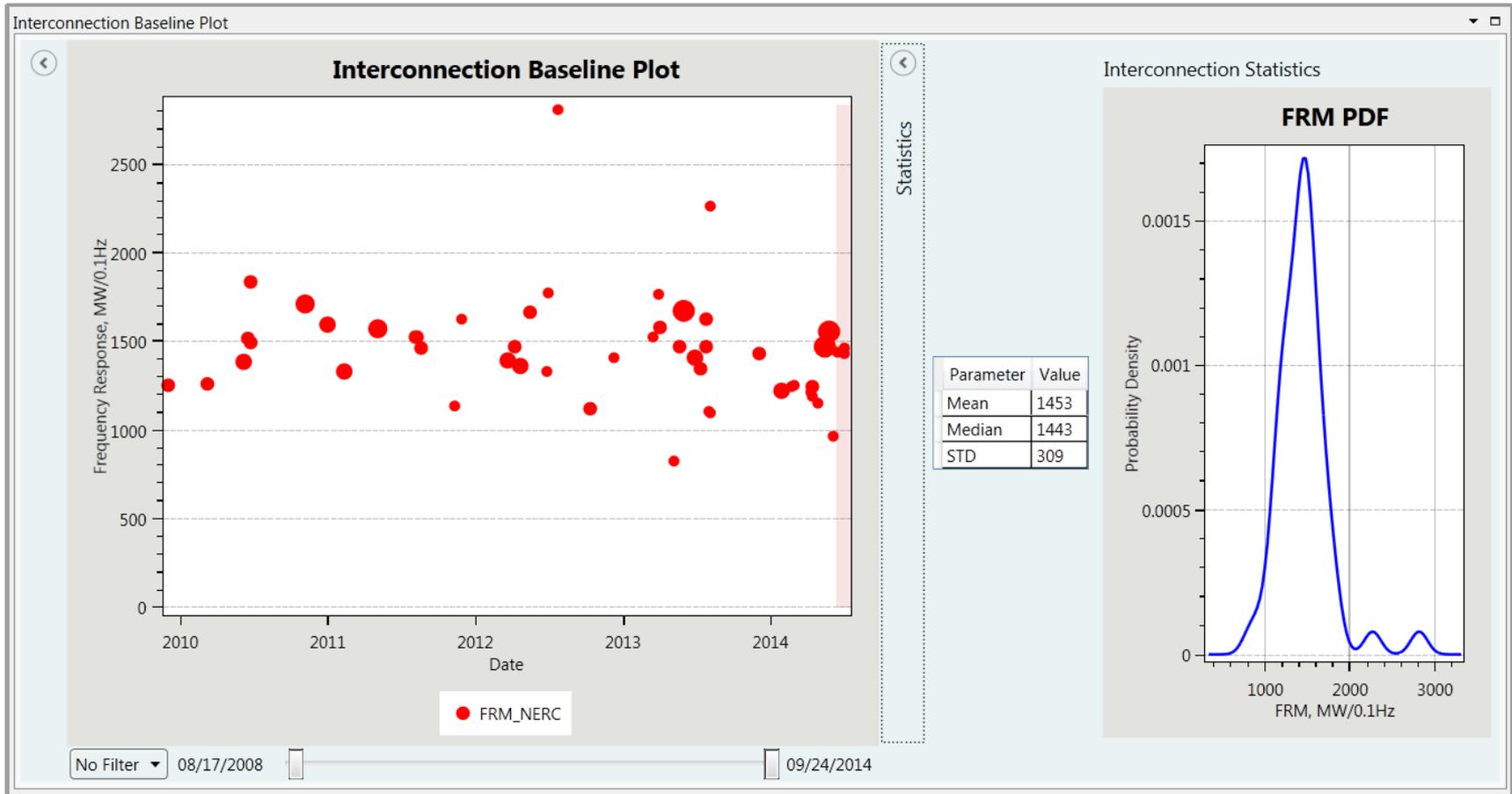
*Western Interconnection*



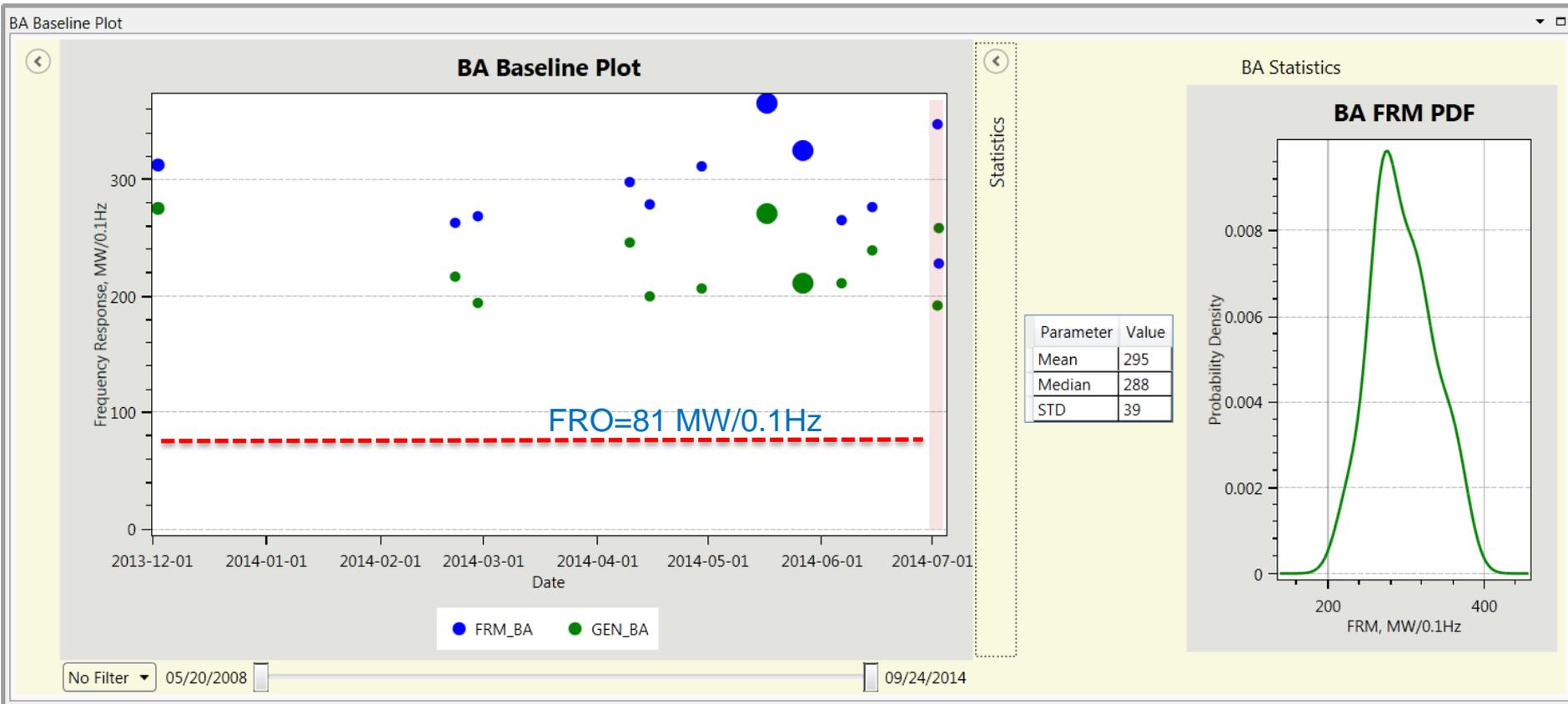
# FRAT main GUI



# Interconnection Performance



# Balancing Authority Performance

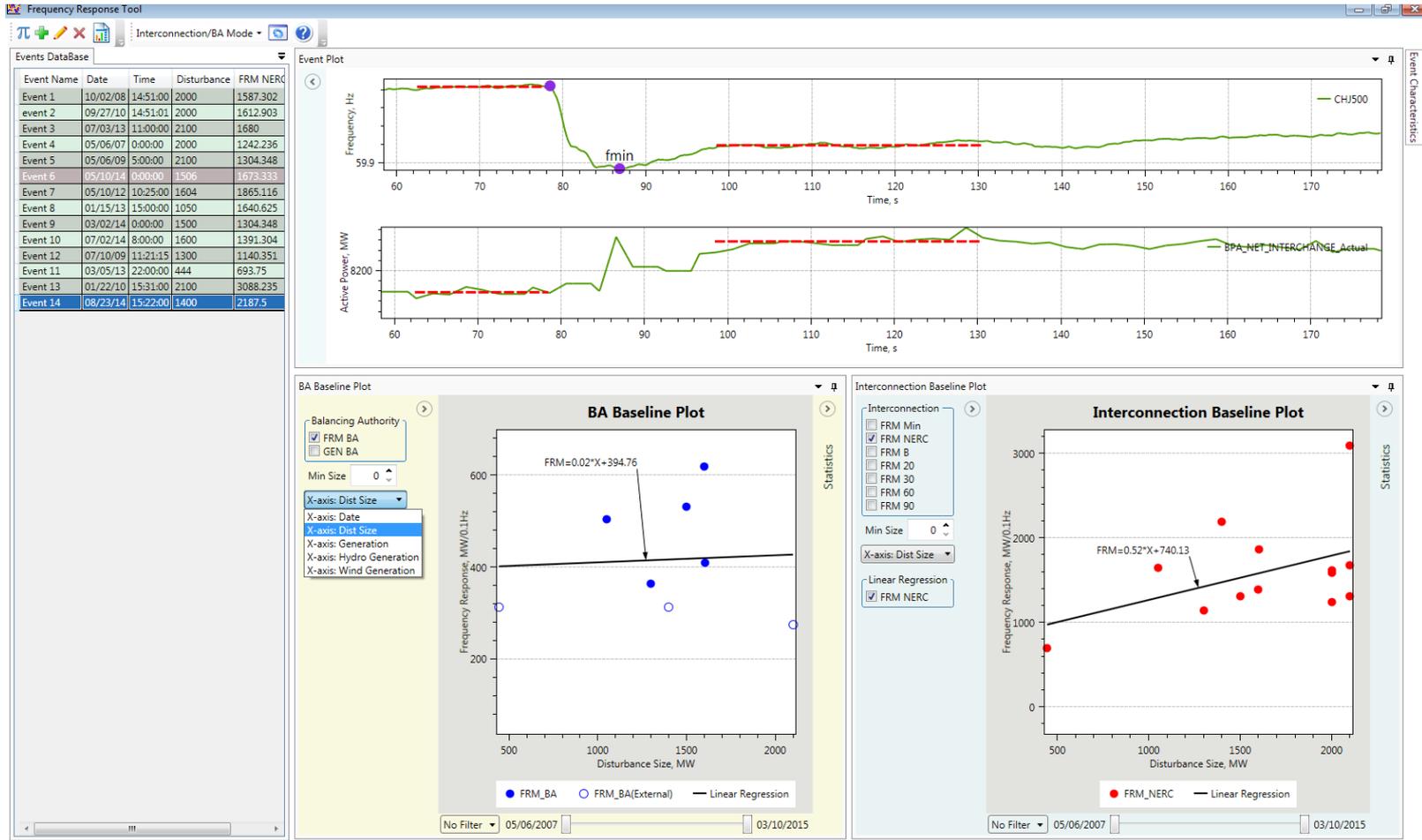


\*Interchange response is measured for compliance with NERC BAL-003-1

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

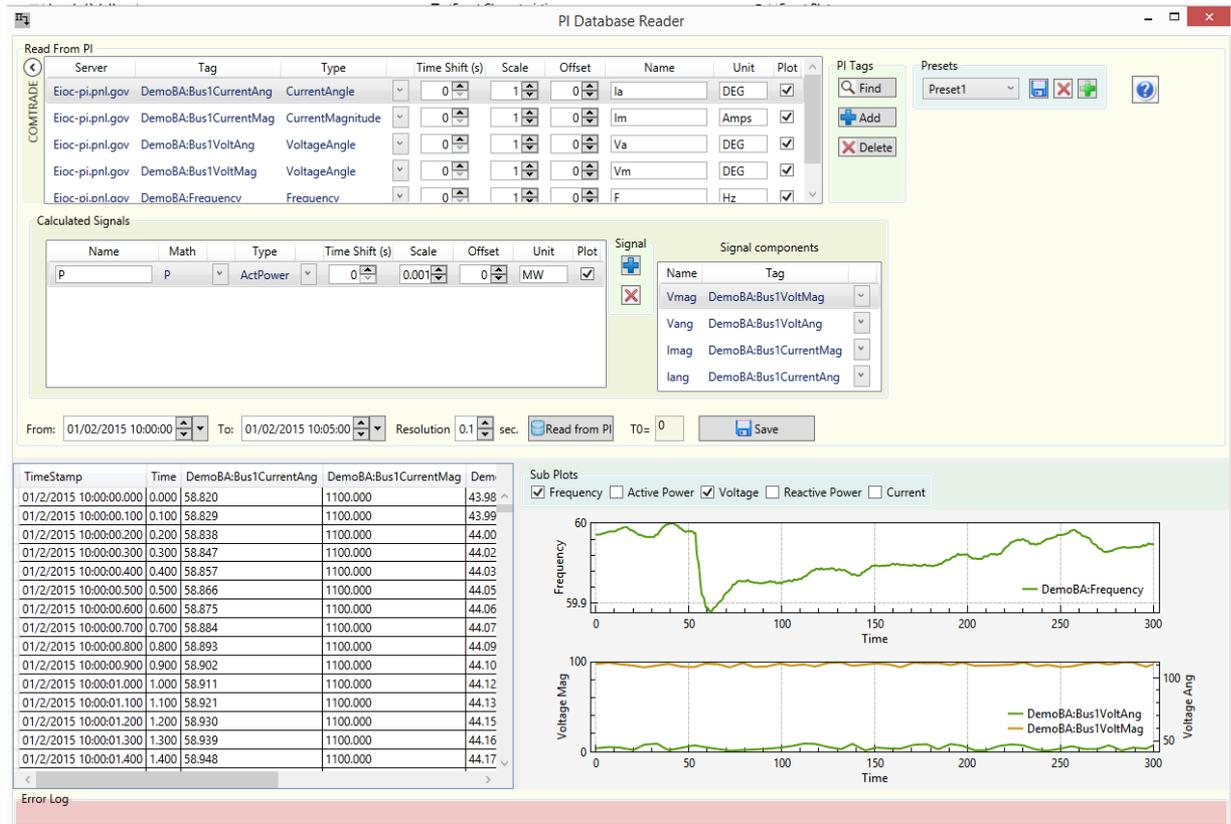


# Baselining



# OSIsoft PI database support

- Read information from PI server
- Configurable presets
- Time-series aligning
- Simple math operations (Sum of several signals, P and Q calculation)



# Automated reporting

User defined reporting range

Export to Excel

Report

Interconnection

Add Events

BA

From  To

Table1 - Excel

Event Name	Event Date	Event Time	Event Time (Local)	Time Zone	Disturbance	Value A	Value B	Point C	Point D	FA_FB	FA_FC	FRM_B	FRM_C	Time C	Time D	Time C - M	Time D - M	Screen	BA	Event	BA	Disturbance	Input	File	Comments
Event 1	10/2/2014 0:00	5:06:00	11/9/2014 21:00 Pacific Std	2000	59.68	59.932	59.772	NaN	0.138	0.106	1561.5	161.538	10.825	NaN	NaN	NaN	NaN	NaN	NERC	FRS1	Disturbance	trip of bus xxx	...	...	...
Event 2	4/22/2014 0:00	11:00:00	4/22/2014 16:30 Pacific Std	2000	59.95	59.925	59.889	NaN	0.67	0.106	2473.181	1886.793	10.061	NaN	NaN	NaN	NaN	NaN	NERC	FRS1	Disturbance	trip of gen xxx	...	...	...
Event 3	11/20/2013 0:00	3:06:00	11/7/2013 16:00 Pacific Std	2000	59.955	59.925	59.889	NaN	0.67	0.106	1265.716	2169.811	9.489	NaN	NaN	NaN	NaN	NaN	NERC	FRS1	Disturbance	trip of gen xxx	...	...	...
Event 4	2/6/2014 0:00	3:06:00	7/3/2014 17:00 Pacific Std	1300	59.954	59.926	59.889	NaN	0.068	0.105	1911.735	1218.095	9.654	NaN	NaN	NaN	NaN	NaN	NERC	FRS1	Disturbance	trip of Gen A	...	...	...
Event 5	2/9/2013 0:00	2:06:00	2/9/2013 18:00 Pacific Std	1300	60.009	59.52	59.511	NaN	0.089	0.138	1220.900	797.221	7.431	NaN	NaN	NaN	NaN	Yes	Yes	Yes	Yes	No	...	...	...

Report

Add Event Plot

3/10/2015 3:52:38 PM

### Frequency Response Analysis Report

Event Name	Event Date	Event Time	Disturbance	Load Loss	Time of Loss	FRM C	FRM BA	Gen Response
Event 1	10/2/2014	14:51:00	2000	1000	5	1587.0	0	0
Event 2	9/27/2014	14:51:00	444	10	1612.0	0	0	0
Event 3	2010/01	11:00:00	2100	5	903	0	0	0
Event 4	5/6/2012	00:00:00	2000	500	11	1242.0	0	0
Event 5	5/6/2010	5:00:00	2100	10	1304.0	0	0	0
Event 6	2014/01	00:00:00	1500	6	348	0	0	0
Event 7	5/10/2010	00:00:00	2100	10	1673.0	216.9	246.6	0
Event 8	5/10/2010	10:25:00	1604	650	5	1865.0	409.6	260.3
Event 9	2012/01	15:00:00	1050	700	5	116.0	82	49
Event 10	1/15/2013	15:00:00	1050	700	5	1640.0	204.1	398.7
Event 11	2013/01	00:00:00	1500	100	10	625.66	67	0
Event 12	3/2/2010	00:00:00	1500	100	10	1304.0	331.8	444.4
Event 13	2/2/2010	8:00:00	1600	100	10	348	3	0
Event 14	7/2/2010	8:00:00	1500	100	10	1391.0	619.2	529.0
Event 15	7/10/2010	11:21:00	1300	100	10	304.88	79	0
Event 16	7/10/2010	11:21:00	1300	100	10	1140.0	303.3	273.0
Event 17	2009/15	00:00:00	1500	100	10	351.38	39	0
Event 18	3/5/2010	22:00:00	444	10	10	693.7	312.6	213.45
Event 19	1/13/2010	00:00:00	2100	10	10	1013.0	58	5
Event 20	1/22/2010	15:31:00	2100	10	10	3088.0	274.3	192.6
Event 21	2/10/2010	00:00:00	1500	10	10	235.37	43	0
Event 22	8/23/2014	15:22:14	1490	10	10	2187.0	312.3	208.5
Event 23	2014/01	00:00:00	1500	10	10	5.30	23	0

Interconnection Baseline Plot

Event1: "Event 1"

#### Event Characteristics Table

Event Name	Event Date	Event Time	Disturbance	Load Loss	Time of Loss	Initial Frequency	Initial Frequency	FRM NERC	FRM Min
Event 1	10/2/2014	14:51:00	2000	1000	5	62.45	59.979	1587.302	485.437
Event 2	9/27/2014	14:51:00	444	10	10	62.45	59.854	1612.903	900.901
Event 3	2010/01	11:00:00	2100	5	10	62.45	59.773	FRM Min	FRM Min

Frequency Plot

Active Power Plot

Event2: "event 2"

#### Event Characteristics Table

Event Name	Event Date	Event Time	Disturbance	Load Loss	Time of Loss	Initial Frequency	Initial Frequency	FRM NERC	FRM Min
event 2	9/27/2014	14:51:00	2000	10	10	62.45	59.854	1612.903	900.901
Event 1	10/2/2014	14:51:00	2000	1000	5	62.45	59.979	1587.302	485.437



# Export report to Word



5/17/2016 1:56:06 PM

## Interconnection Frequency Response Analysis Report

Interconnection Name: WECC  
 From: 11/19/2013  
 To: 05/17/2016  
 Number of M4 events: 1  
 Number of BAL-003 events: 1

Event Name	Event Date	Event Time (UTC)	Event Time (Local)	Time Zone	Disturbance Size	Value A	Value B	Value C
Event 1	11/10/2014	5:00:00	01/09/2014 21:00:00	Pacific Standard Time	2000	59.98	59.852	59.852
Event 2	4/22/2014	13:10:00	04/22/2014 06:10:00	Pacific Daylight Time	2000	59.995	59.925	59.925
Event 3	11/20/2013	0:00:00	11/19/2013 16:00:00	Pacific Standard Time	2300	59.995	59.925	59.925
Event 4	7/6/2014	0:00:00	07/05/2014 17:00:00	Pacific Daylight Time	1300	59.994	59.926	59.926
Event 5	2/9/2015	02:00:00	02/08/2015 18:00:00	Pacific Standard Time	1100	60.009	59.92	59.92

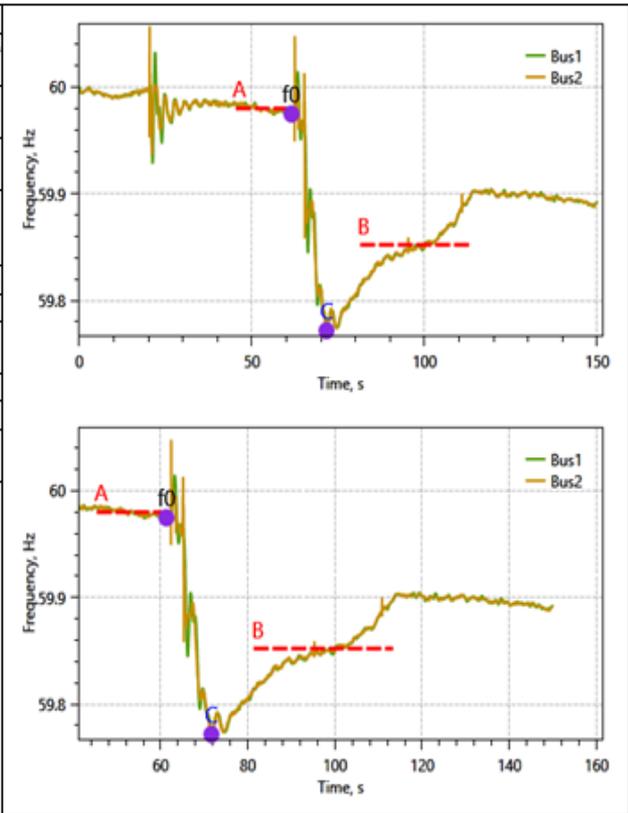
**Interconnection Baseline Plot**

● FRM\_NERC — Linear Regression



## Event 1

Event Name	Event 1
Event Description	trip of bus xxx
UTC Time	01/10/2014 05:00:00
Local Time	01/09/2014 21:00:00
Time Zone	Pacific Standard Time
M4 Flag	No
BAL003 Flag	No
MW Loss [MW]	2000
A-B [mHz]	128
A-C [mHz]	208
FRM_B [MW/0.1Hz]	1562.5
FRM_C [MW/0.1Hz]	961.538



# Deliverables FY16

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- Conference paper will be presented at IEEE General meeting in July 2016.
- Latest version of the Frequency Response Analysis Tool and software documentation. Available at:
  - PNNL web page: <https://svn.pnl.gov/FRTTool>
  - NASPI software exchange portal

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#	Milestone/Deliverable	Target Date
1	<i>Tool specification</i>	December 2014 (completed)
2	<i>Prototype version of the tool</i>	March 2015 (completed)
3	<i>Incorporate user feedback and revise prototype</i>	September 2015 (completed)
4	<i>Final tool release</i>	December 2015 (completed)

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# Industry Outreach

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The FRAT application has been presented at multiple industrial events including:

- NERC Synchronized Measurement Subcommittee (SMS)
- NASPI working group meeting
- GIGRE Grid of the Future Symposium
- WECC Joint Synchronized Information Subcommittee (JSIS)
- WECC Modeling and Validation Work Group (MVWG)
- Webinars for different electrical utilities
- IEEE General Meeting (to be presented)



# Risk factors

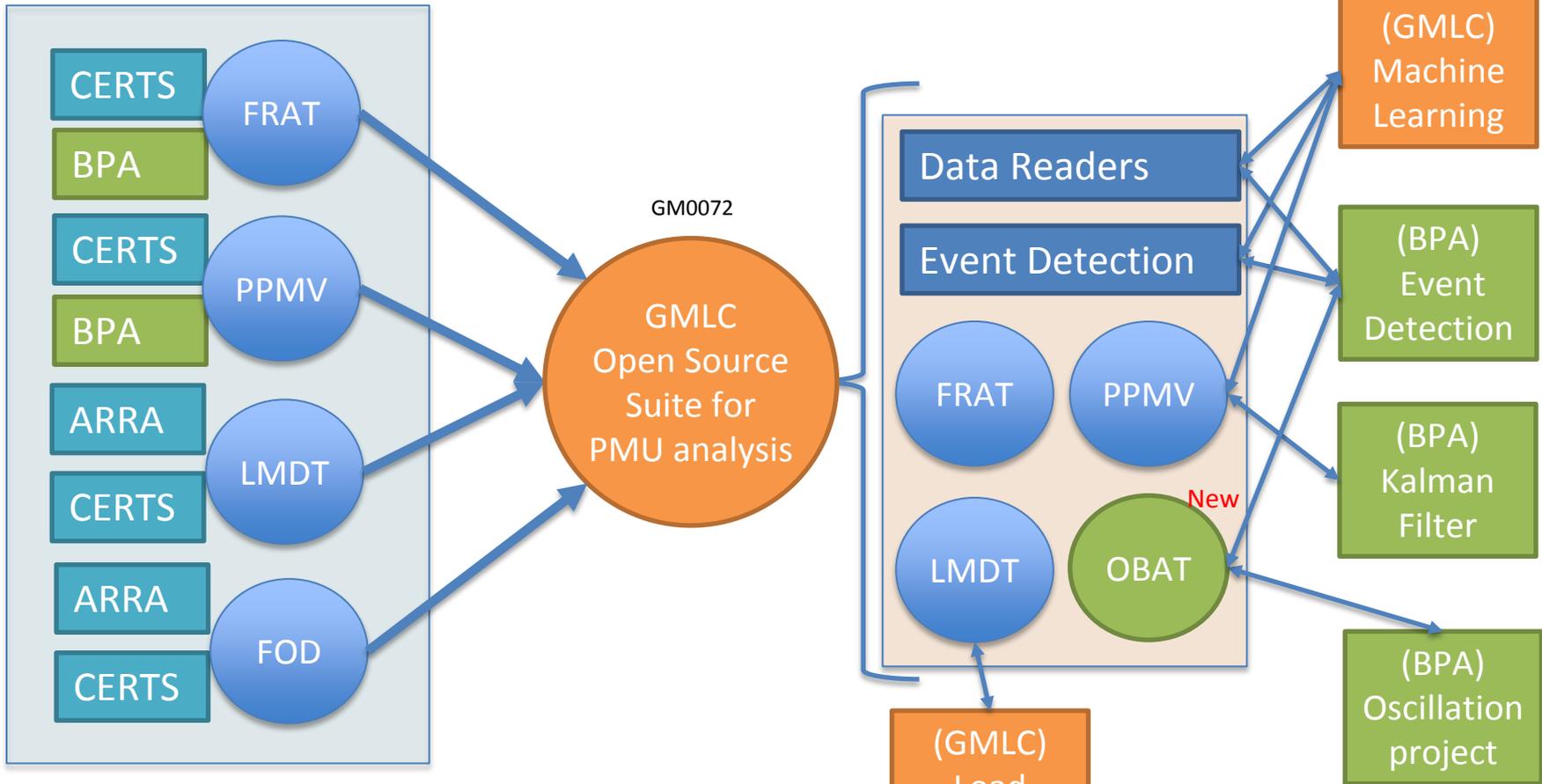
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- Risk factors are low.
- Feedback and guidance from industrial users are very important for the success of the project.



# Future plans

## Completed Projects



FRAT – Frequency Response Analysis Tool  
 PPMV – Power Plant Model Validation Tool  
 LMDT – Load Modeling Data Tool  
 FOD – Forced Oscillation Detection  
 OBAT – Oscillation Baseline and Analysis Tool

# Open Platform for Engineering Applications

- Based on Open Source Components
  - Extended WPF Toolkit™
  - OxyPlot
  - Math.NET
- Create building blocks and solutions for future and 3<sup>rd</sup> party applications
- Common data structure and data exchange protocols
- Support external modules/solvers
  - Oscillation Analysis
  - Model Calibration

