

IBR Synchrophasor Perspective

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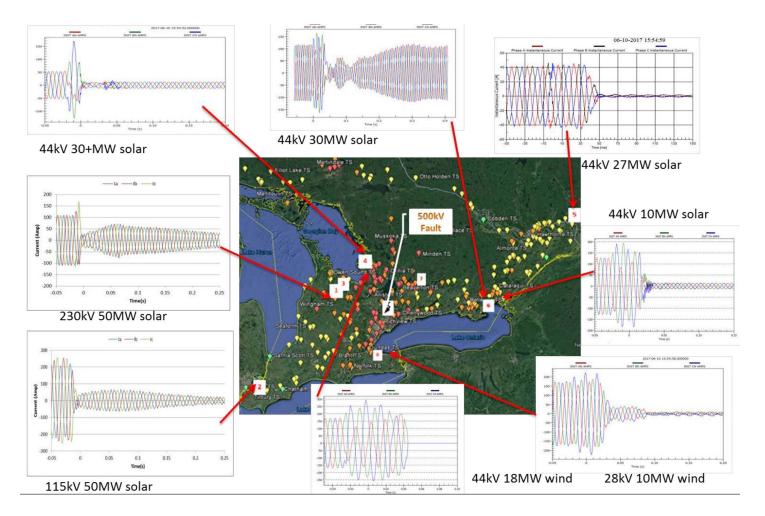
PNNL-SA-190422





IBR Monitoring and Performance Evaluation

- Utilizing measurements at different time-scales and locations.
- □ Evaluating generator behavior during steady state and transients.
- □ Practical challenges evaluating a wide array of generators.
- Using synchorphasor vs. point on wave data.
- □ Bandwidth and analytics challenges.



*HydroOne renewable monitoring – system wide event*¹

[1] Li, C. (2019). Inverter-Based Resource Monitoring and Event Investigations. Paper presented at the NATF/EPRI/NERC Power System Modeling Conference, Novi, MI. https://www.nerc.com/comm/PC/SAMS%20Agendas%20Highlights%20Minutes/2019 NERC-NATFEPRI Power System Modeling Workshop Presentations.pdf PNNL-SA-190422



IBR Monitoring and Performance Evaluation

PROGRESS MATRIX Project – Jointly funded by OE and SETO Project Manager – Jim Follum, PNNL Objectives:

- Develop advanced measurement capabilities and analytics
- Accelerate adoption of IBRs
- Improve the reliability and resilience of the bulk power system

Thanks to colleague Kaustav Chatterjee for slide contributions









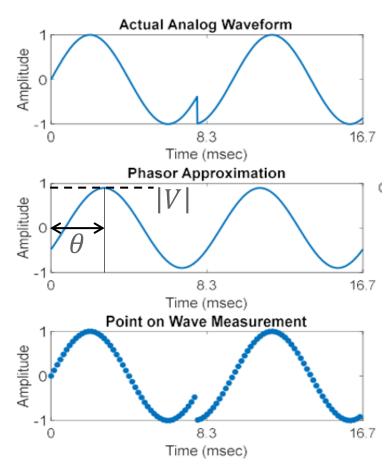


M c E A C H E R N



Measurements – where and how much?

- □ IBR measurements at point of interconnection limited availability
- Bandwidth considerations for Point on Wave data.
- □ Maximizing the use of data available at substations.
- □ Align generator monitoring applications with available data.
- □ Sychrophasor measurement for monitoring Generator Scorecard.
- □ Point on wave data for monitoring selective data transmission.



Matching measurements to applications¹

Compare PMU to POW fidelity

to actual waveform

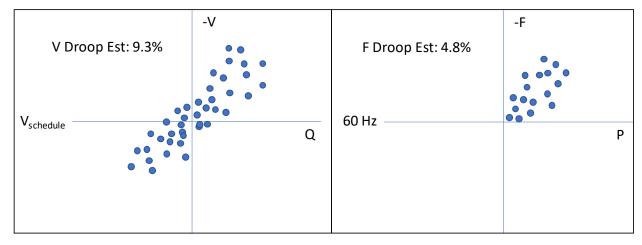


Generator Scorecard

- Evaluating generator performance using PMU data Is the droop maintained as indicated? Is reactive power absorbed/fed as required? Are voltage schedules met?
- Monitoring IBR plants across operating conditions.
- Practical challenges of measuring Frequency Response (FRM) and voltage response.
- Comparing individual generator behavior with others.
- Scan through PMU data to find events that surpass a frequency or voltage magnitude threshold.
- Capture events and "score" generator performance.
- Implemented on DOE Archive Walker based event detection and generator response scoring.

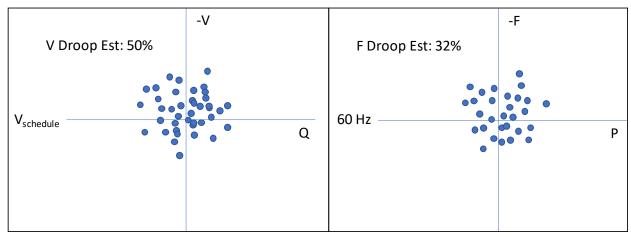
Generator 1: Pass

Ridethrough: 89 of 90 disturbances



Generator 2: Fail

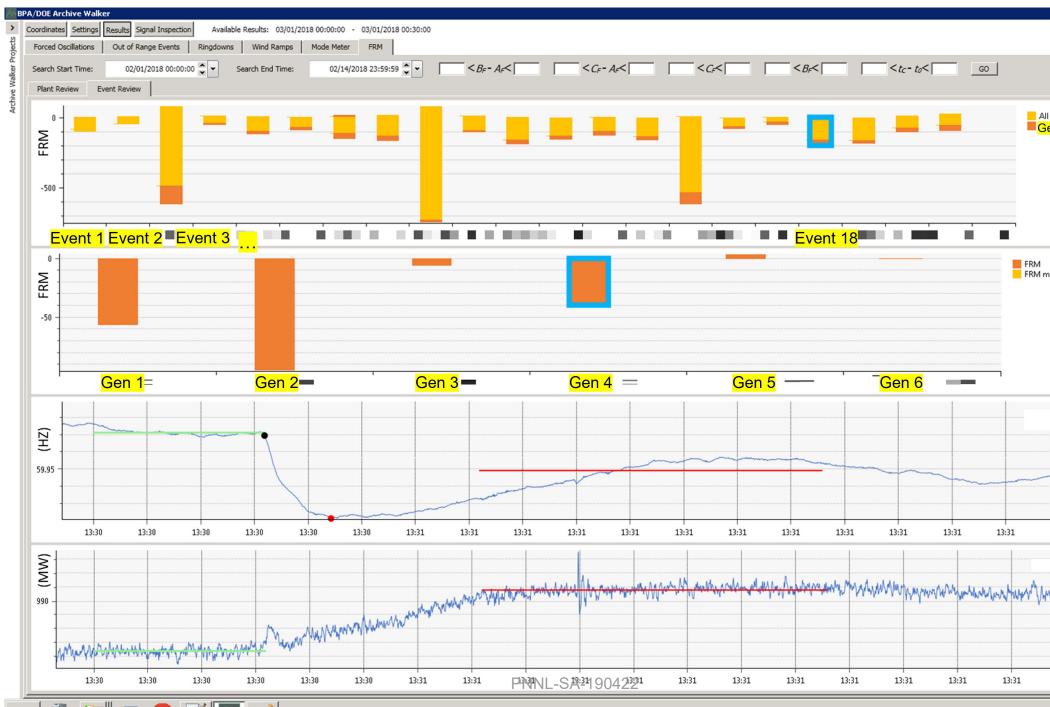
Ridethrough: 75 of 90 disturbances





Generator Scorecard - FRM

Northwest



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	to	BA FRM	с	ΔF	ΔΡΒΑ
ll other		-95.1688	60.039	0.045876	-43.6587
Sen 4		-35.1508	60.0379	0.020169	-7.0885
		-536.5641	60.0477	0.005697	-30.5492
	THE PART	-34.2597	59.9568	-0.02567	8.799
	DICULDU.	-104.5639	60.0428		-27.8353
		-81.3385	60.0385		-24.7576
		-140.1915	60.045		-43.2803
	di name	6.9943	59.9849	-0.05747	
		-144.5003	59.9595	-0.01426	
	and the second	-664.9107 -88.1208	60.0674 60.0566		-134.002 -27.1012
		-179.2491	59.9498	-0.01642	
	100.0100	-Infinity	60.0361		-37.0428
		Infinity	60.0315	0.003657	
		-157.509	60.0457	0.031759	
manual	ting out	-607.0391	60.0515	0.005847	
		-76.7013	59.9491	-0.0276	21.1687
	10.010.000	-43.1755	59.9469	-0.02789	12.0447
	1010010-0	-194.7609	59.9212	-0.02208	42.9967
	1.111.11.1	-179.2889	59.9599	-0.02476	44.4083
		-88.6437	59.9349	-0.02016	
		-64.7354	59.9285	-0.02468	15.9732
	Plant	FRM	FRM ma	inual i	ΔPplant
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	-9	5.018	20.9706		
	-5.9343		1.3104		
		9.656	8.7587		
		.9944			56126
		.43905		0.0	96938
İ					
~					
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	Discord SDM for all plants				
	Discard FRM for all Plants				
MM	Adjust to by seconds Go				
	, logoot at				
	Set Manual FRM to Go				
13:32					



Pacific

Generator Scorecard – FRM

Northwest



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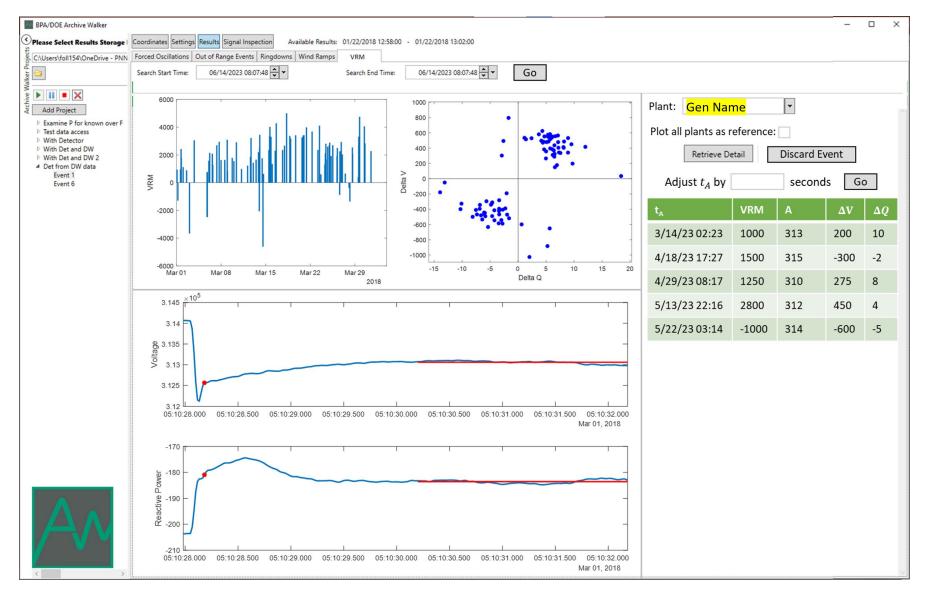
	to	BA FRM	с	٨F	ΔΡΒΑ	
ner		-95.1688	60.039	0.045876		
2		-35.1508	60.0379	0.020169	-7.0885	
		-536.5641	60.0477	0.005697	-30.5492	
		-34.2597	59.9568	-0.02567	8.799	
		-104.5639	60.0428	0.026622		
		-81.3385	60.0385	0.03043€		
		-140.1915	60.045	0.030873		
		6.9943	59.9849	-0.05747		
	-	-144.5003	59.9595	-0.01426		
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		-179.2491	59.9498	-0.01642		
		-1/9.2491 -Infinity	60.0361	0.020242		
		Infinity	60.0315	0.003657		
		-157.509	60.0457	0.031759		
lal		-607.0391	60.0515	0.005847		
		-76.7013	59.9491	-0.0276	21.1687	
		-43.1755	59.9469	-0.02789		
		-194.7609	59.9212	-0.02208	42.9967	
		-179.2889	59.9599	-0.02476	44.4083	
		-88.6437	59.9349	-0.02016	17.8814	
		-64.7354	59.9285	-0.02468	15.9732	
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	40.	4012		0.1		
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	-69 -37 -13 34.	91.4877 7.0867 8.553		-13 -7.4 -2.7 6.8	9.3646 4832 7351	
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	-69 -37 -13 34.	91.4877 7.0867 8.553 .0115		-13 -7.4 -2.7 6.8	9.3646 4832 7351 613	
	-69 -37 -13 34.	91.4877 7.0867 8.553 .0115		-13 -7.4 -2.7 6.8	9.3646 4832 7351 613	
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L:59	-69 -37 -13 34.	1.4877 2.0867 3.553 .0115 239		-13 -7.4 -2.7 6.8 0.5	9.3646 4832 7351 613	
L:59	-69 -37 -13 34.	91.4877 7.0867 8.553 .0115 7239		-13 -7.4 -2.7 6.8 0.5	9.3646 4832 7351 613	
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	-65 -37 -13 34, 2.7	11.4877 .0867 .553 0115 239	4 for this P 4 for all Pla -	-13 -7.4 -2.7 6.8 0.5	9.3646 4832 7351 613	
L:59	-65 -37 -13 34, 2.7	11.4877 .0867 .553 0115 239	4 for this P 4 for all Pla -	-13 -7.4 -2.7 6.8 0.5	9.3646 4832 7351 613	
L:59	-65 -37 -13 34, 2.7	11.4877 .0867 .553 0115 239	4 for this P 4 for all Pla -	-13 -7.4 -2.7 6.8 0.5	9.3646 4832 7351 613	
1.59	-65 -37 -13 34, 2.7	11.4877 .0867 .553 0115 239	4 for this P 4 for all Pla -	-13 -7.4 -2.7 6.8 0.5	9.3646 4832 7351 613	
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Generator Scorecard – Voltage events

- Frequency is global but voltage is local.
- Practical challenges to evaluate voltage response from every generator in the system.
- Factors affecting voltage response - plant settings, voltage schedules, power factor, etc.
- Is the generator "usually" behaving with an expected response?



PNMockup4of the voltage response portion of the Generator Scorecard



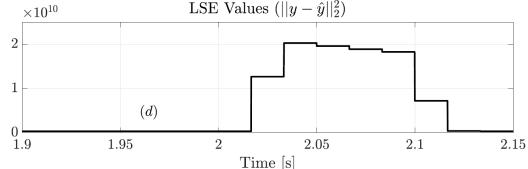
Point on Wave – IBR Monitoring

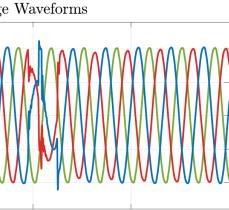
- Non-sinusoidal measurement data during events -unreliable phasor estimates. E.g. Blue Cut Fire, Canyon Fire.
- Trust flag to validate correctness of phasor measurement.
- Augmenting ability for informed decisions at the control room.
- Detecting the occurrence of an event and selectively transmitting POW data for the event window – as opposed to continuous streaming.
- A non-linear least squares based PMU algorithm with **Trust Metric**
- Communicating selective POW over existing communication channels.

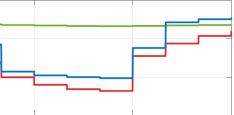
K Chatterjee, D Tarter, J Follum, A Riepnieks, "A Nonlinear Least Squares Phasor Estimation Algorithm with a Trust Metric" Innovative Smart Grid Technologies, North America 2024 [Submitted]

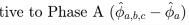


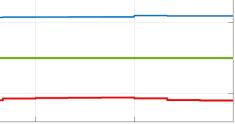
Three-phase Voltage Waveforms —Phase A —Phase B —Phase C 20Voltage [kV] (a)Estimates of Signal Amplitudes Voltage [kV] 10 00 (b)18 Estimates of Phase Angles Relative to Phase A $(\hat{\phi}_{a,b,c} - \hat{\phi}_a)$ 100 [deg] 0 -100 (c)LSE Values $(||y - \hat{y}||_2^2)$ $imes 10^{10}$







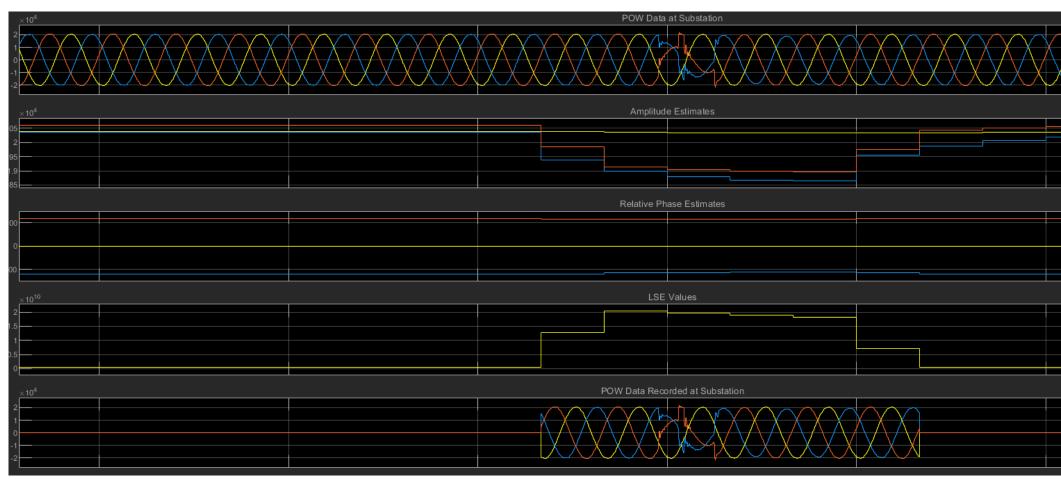






Point on Wave – IBR Monitoring

Data source: Grid Event Signature Library Event 907



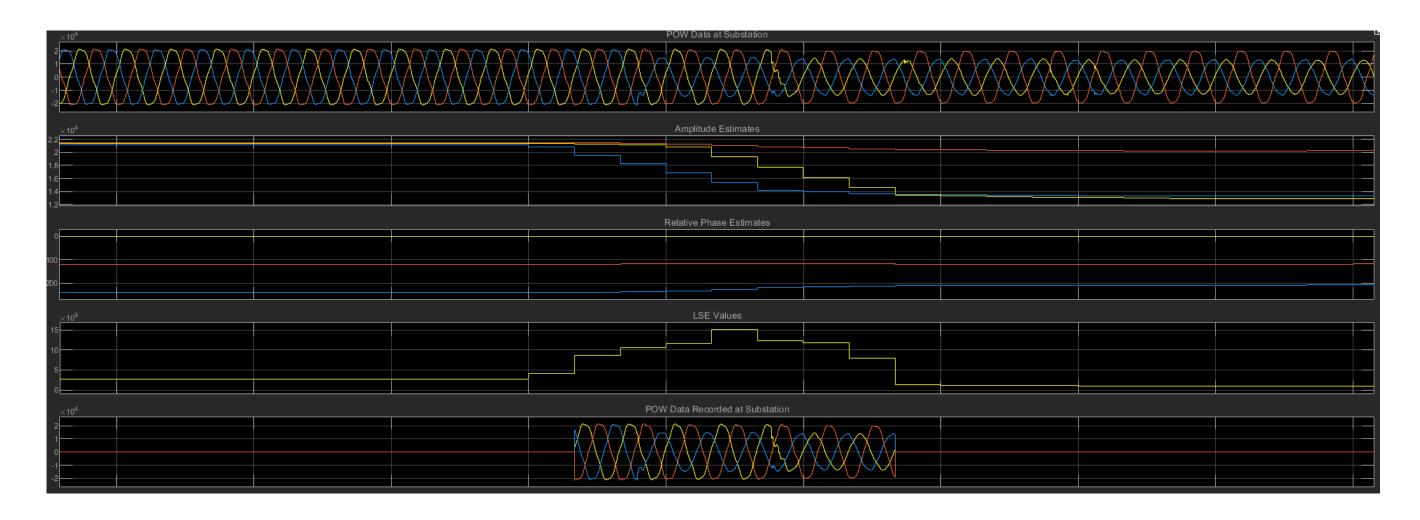
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Point on Wave – IBR Monitoring

Data source: Grid Event Signature Library Event 677





- The right tool for the right job in an IBR-rich grid.
- Sychrophasor data applications to monitor frequency and voltage response.
- Selective Point on Wave data transmission when PMU data trust low.
- Challenges when POW is unavailable, unreliable, has gaps.
- Future directions:
 - IBR Performance Response and Analytics Monitoring (IPRAM) Task Force.
 - IBR monitoring using Continuous Point on Wave.
 - Event capture with customizable POW triggering conditions.
 - Distributed solutions for storing and analyzing.



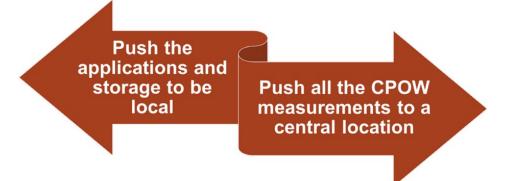
IBR Performance Monitoring and Analysis

North American Synchrophasor Initiative

Technical Report

Authors/Contributors

NASPI EATT IBR Performance Response and Analytics Monitoring (IPRAM) Task Force



VASP North American SynchroPhasor Initiative



Thank you

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