

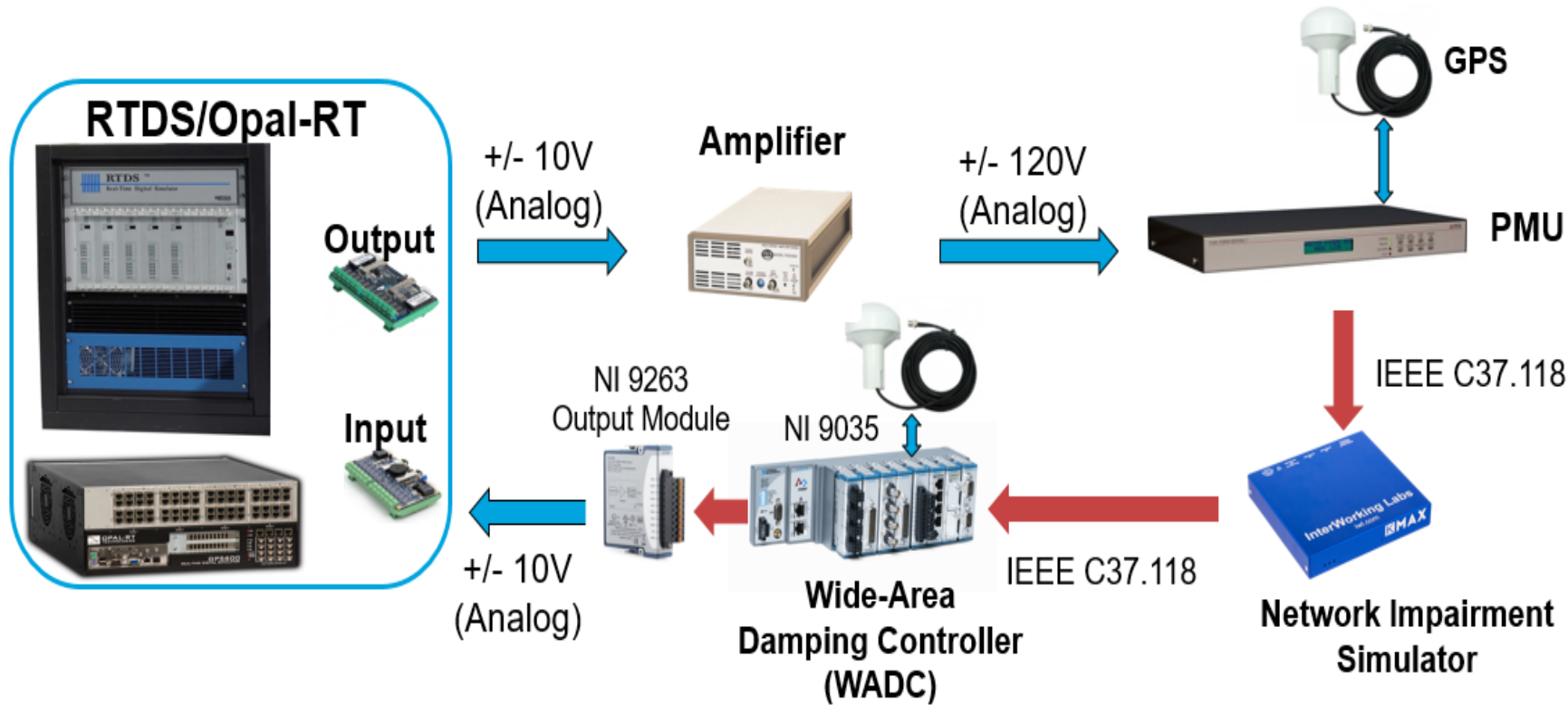
Summary of EPRI Synchrophasor Related Activities

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October 29, 2019



1. Synchrophasor-Based Wide Area Oscillations Damping Controller



In collaboration with University Tennessee Knoxville (UTK)

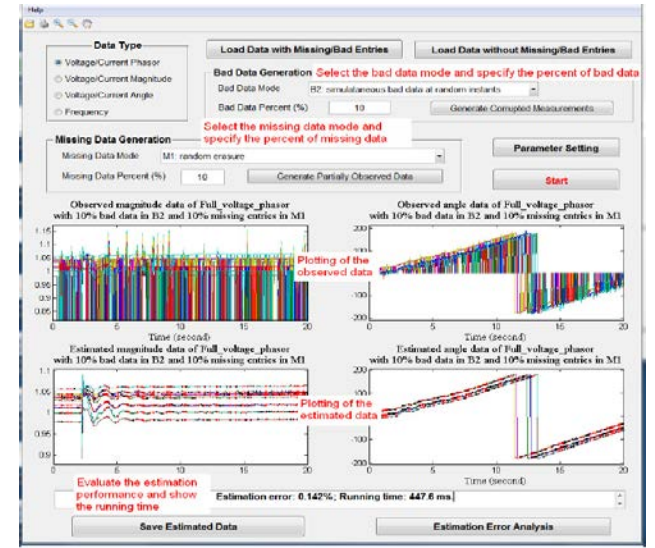
- Improved Damping of Target Inter-area/Intra-area Oscillations Mode
- Application of Synchrophasor Technology in Closed Loop Wide Area Control

- WADC via additional input to generator excitation system or FACTS/HVDC controller
- Adaptive controller
 - Measurement-derived transfer function model
- Ongoing case studies with NYPA, TERNA (Italy) & SEC (Saudi Arabia)
- **Ongoing: Hardware-In-the-Loop (RTDS/Opal-RT) implementation and demos**

2. Data Quality Conditioning of Streaming Synchrophasor Data

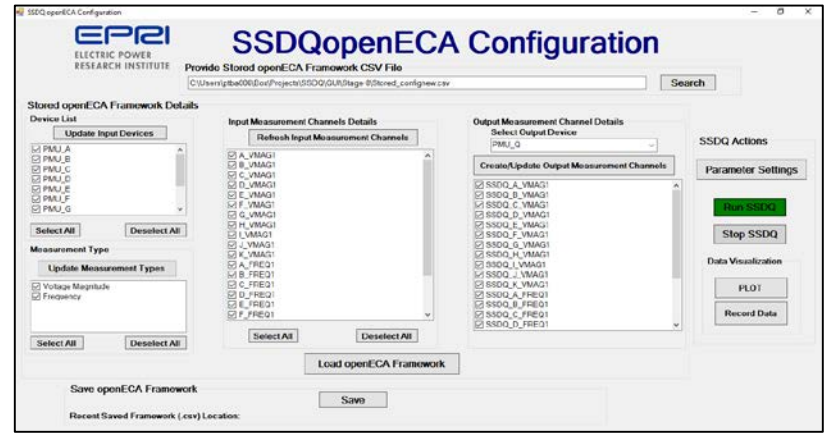
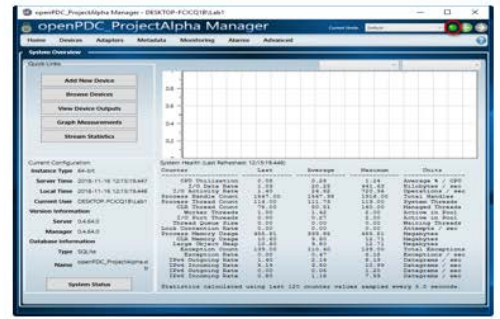
- Goal: Improve synchrophasor data quality by estimating missing data and replacing bad data in synchrophasor streams
- Model free technique, no need for topology information or system parameters
- Computationally efficient for real-time implementation
- Algorithms have been tested with recorded synchrophasor data provided by EPRI members
- Demos with streaming synchrophasor data hosted by utilities/ISOs
- Collaboration with vendors for implementation in commercial platforms

Offline SSDQ Tool



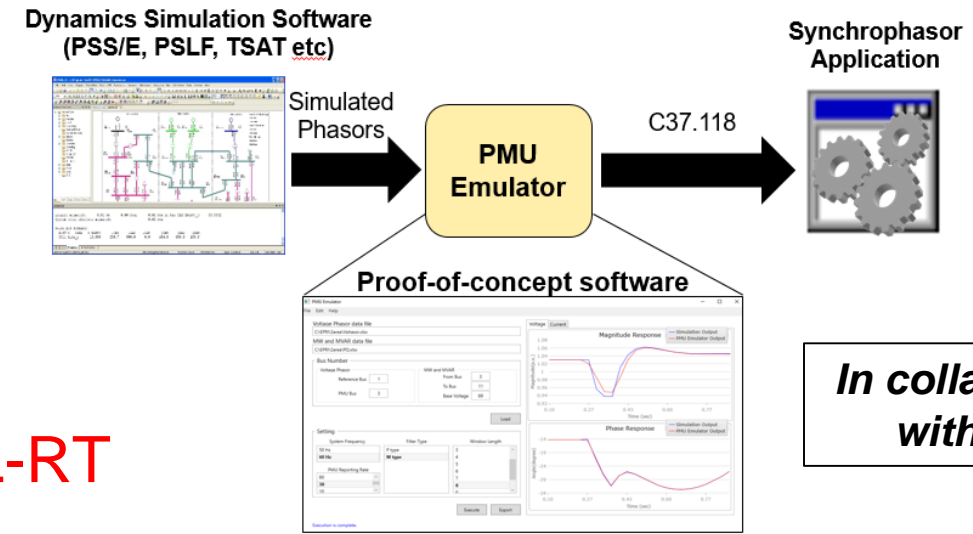
In collaboration with RPI

Online SSDQ Tool (OpenPDC & OpenECA)



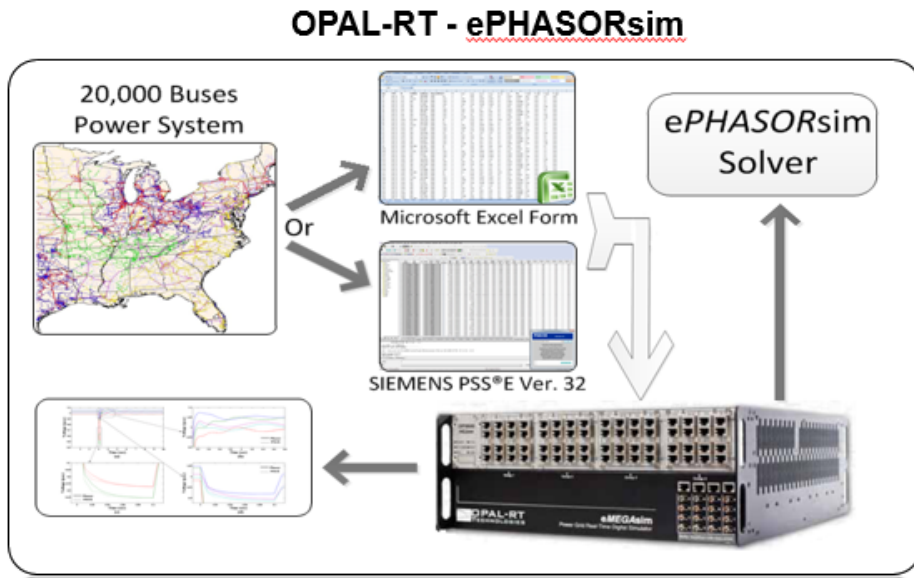
3. PMU Emulator

- Interfaced with power system dynamics simulators to produce “simulated synchrophasors” taking into account PMUs internal signal processing
- Implementation of PMU Emulator with OPAL-RT ePHASORSIM**



In collaboration with WSU

Vendor Engagement



The screenshot shows the 'Block Parameters: PMU' configuration window. It includes a description of the implementation following IEEE C37.118.1-2011 (Annex C) and a list of parameters:

- PMU Name: 'busXYZ'
- Number of Channels: 1
- Nominal frequency (Hz): 60
- Filter Type: Measurement
- PMU Reporting Rate (50Hz): 10
- PMU Reporting Rate (60Hz): 30
- ePHASORSim Time-Step (s): 0.004
- Number of Samples per Cycle: 100
- Window Length (Cycle): 5

4. Machine Learning Using Synchrophasor Data

- Event Identification (time, type & location) through supervised & unsupervised machine learning
- **Update:** Synchrophasor Based Machine Learning (SBML) software

Parameter Selection

1. Machine Learning Method Selection

Supervised Learning: Nearest Neighbors, Decision Tree, Support Vector Machine

Unsupervised Learning: Naive Bayes, Logistic Regression, Hybrid Method

Event Time, Event Type, Event Location

2. Event Data Selection and Preprocessing

Load, Preprocess

3. Data Visualization

Time Series, Statistics, Clear

4. Training/Testing/Estimation Event Selection

Training: Number of Events (Random/Ordered)

Time Range: From 1/1/2000 12:00 AM, To 1/1/2000 12:00 AM

Testing: Event 1, Event 2, Event 3, Event 4, Event 5, Event 6

Estimation: Event 12, Event 13, Event 14, Event 15, Event 16, Event 17

Learning

Click to Learn

100%

Event Identification Results

Event 1

Confirm

Time	Detected	Truth
3/1/2000, 5:6:5.66.		3/1/2000, 5:6:5.66.

Line/Generator Trip

Type	Detected	Truth
Line Trip	<input checked="" type="radio"/>	<input checked="" type="radio"/>
Generator Trip	<input type="radio"/>	<input type="radio"/>

Line Faults

Type	Detected	Truth
Three Phase Fault	<input type="radio"/>	<input type="radio"/>
Single Phase Fault	<input type="radio"/>	<input type="radio"/>
Phase To Phase Fault	<input type="radio"/>	<input type="radio"/>

Event Location

	Location Detection
Detected	Bus 51 (PMU 51).
Truth	Line 5-64.

Unsupervised Visualization

Event Time, Event Type, Event Location

Event 1

Principal Component Analysis, 3D Visualization

3D visualization for event points

Principal component 1, Principal component 2, Principal component 3

In collaboration with ASU

5. Synchrophasor Applications Database

Search Results:

Agency Name	Application Type	Vendor Name	Tool Name
ERCOT	Situational Awareness	EPG	RTDMS
ERCOT	Oscillation Detection	EPG	RTDMS
ERCOT	Event Analysis	EPG	PGDA
ERCOT	Model Validation	Mathworks Powertech Labs, Inc.	MATLAB TSAT
ERCOT	Operator Training	EPG	PSOT
ISO-NE	Voltage Stability	V&R Energy	ROSE
ISO-NE	Event Detection	GE	PhasorPoint
ISO-NE	Oscillation Detection	GE	PhasorPoint OSL
ISO-NE	Model Validation	Powertech Labs, Inc.	TSAT
ISO-NE	Data Quality Management	In-house	DQMS
NYISO	Situational Awareness	EPG	RTDMS
NYISO	Voltage Stability	ABB	Phasor Enhanced Voltage Stability M
NYISO	State Estimation	ABB	Phasor Enhanced State Estimator
NYISO	Oscillation Detection	EPG	RTDMS
NYISO	Event Analysis	EPG	PGDA
NYPA	Model Validation	EPRI	SVSMV
OG&E	Situational Awareness	In-house	PhasorView
OG&E	Event Detection	In-house	PhasorView
OG&E	Oscillation Detection	In-house	PhasorView

Alstom/GE's PhasorPoint

Description:
e-terraphasorpoint is an advanced, fully integrated, smart grid ready suite of products for the 21st century grid. Transmission operators must maintain stable operation of the power system and increase the use of assets, while aging infrastructure and a changing generation profile introduce new challenges. e-terraphasorpoint can bring great insight, reducing costs through more effective use of power system capacity, safeguarding its stability. This flexible, scalable and extensible phasor-based Wide Area Management System (WAMS) is integrated with the e-terra solutions for Energy Management Systems (EMS), in order to:

- Transform phasor data into actionable information to improve system security and capacity.
- Coordinate WAMS and EMS to produce a unified view of the power system, enhancing operator and analyst decision-making.
- Enable strategic development of the control center systems with the critical involvement of phasor-based information sources.

Key benefits include:

- Mitigate risk of major disturbance
- Relieve transmission constraints.
- Improve dynamic models.
- Fulfill regulatory reporting requirements.
- Improve emergency response.
- Scalable – grow to the largest foreseeable systems.
- Extensible – add new applications when required.

Other details about the product are described in [1].

Built-In Data Quality Management:
GE's built-in functionality for data quality management includes two aspects, which are e-terraphasorpoint PDC processing and synchrophasor applications (i.e.: oscillation detection, state estimation) level data handling. The e-terraphasorpoint PDC processing provides users both live stream statistics and live PMU statistics. Live stream statistics include packet latency, percentage of time quality errors, percentage of missing data frames and last valid data frame. Whereas, live PMU statistics include percentages of GPS lock, valid data, data error and missing data. And the data handling of application level is based on three heuristics. These heuristics are an utilization of PMU data quality status information from the field of PMU.

References:
[1]. "e-terraphasorpoint", GE Software Solutions.
[2]. Alstom/GE "Grid Software Solutions - Built-in Data Quality", presented at NASPI, Mar. 2016.

Model Validation at NYPA

Description:
NYPA has used EPRI's "Static Var System Model Validation" tool to validate the models of a STATCOM (Marcy substation) and an SVC. The generic dynamic Static Var Systems models (also developed by EPRI) were used to parameterize [1], [2]. Figure 1 [2] shows representative results of the model validation.

References:
[1]. EPRI and NYPA, "Model Validation of SVC and STATCOM Using PMU Data", presented at N. ASP, Oct. 2013.
[2]. EPRI and NYPA, "Validation of Generic Models for Stability Analysis of two Large Static Var Systems in New York using PMU Data", presented at IEEE PES GM, Apr. 2014.

- Entries based on publicly available documents
- For each entry, summary description of application and related references

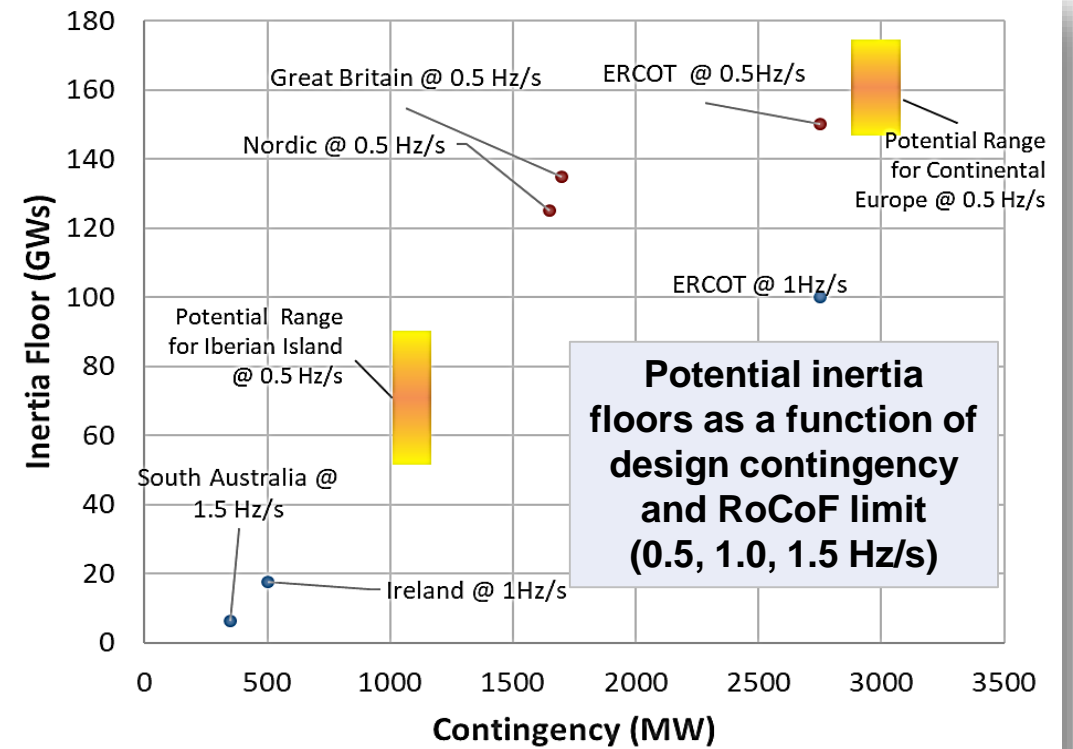
Value: Inform utility/ISO engineers and executive management about uses cases and derived value of synchrophasor technology

6. PMU Based Inertia Monitoring

- With increasing levels of Inverter Based Resources (IBR), system inertia is decreasing
- Growing interest and need for online inertia monitoring – inertia floor
- EPRI white paper “**Online Inertia Estimation & Monitoring - Industry Practices & Research Activities**”

1. Present Industry Practices

2. Research Activities and Proposed Technologies



	Texas (ERCOT)	Great Britain (National Grid)	Ireland (EIRGrid)	Nordic system	Australia (National Electricity Market)
UFLS	59.3 Hz	48.8 Hz	48.85 Hz	48.85 Hz	47.6 Hz
RoCoF	~ 1 Hz/s	0.5 Hz/s	1 Hz/s	0.5 Hz/s	1.5-3.0 Hz/s
Largest Contingency	2.75 GW	1 GW	500 MW	1.65 GW	350 MW
Peak Demand	~73 GW	~60 GW	~6.5 GW	~72 GW	~36 GW
Inertia Floor	100 GWs	135 GWs	23 GWs	125 GWs	6.2 GWs

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