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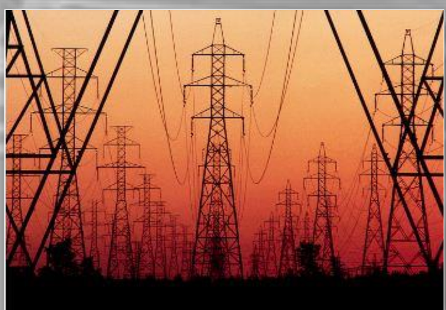
New York State of Opportunity. NY Power Authority

Electric Power Group



Pre-Commercial Demonstration of Direct Non-iterative State Estimator (DNSE+)

NASPI

Project with Quanta, NYPA & EPG

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Disclaimer:

Problem Statement & Background

Project Objective:

Demonstrate functionality and performance of a production-grade Direct Non-iterative State Estimator (DNSE) integrated with NYPA's Energy Management System (EMS) and with an enhanced Real Time Dynamic Monitoring System (RTDMS) synchrophasor platform from Electric Power Group (EPG);

Background:

- DNSE started as an idea by Bruce Fardanesh at NYPA several years ago; also patented
- It was further researched as PhD thesis by Tony Jiang
- DNSE+ (+ added to designate SE with additional components around the estimation "engine")

DNSE+ vs Other State Estimators

Traditional State Estimator:

– runs every 30 sec to several minutes
– takes latest RTU/ICCP analog measurements and breaker status
– solved iteratively (occasional convergence issue)

Linear State Estimator:

– uses PMU data, can run at phasor frame rate
– direct method (no iteration or convergence issues)
– needs large number of PMUs (larger than currently available) to estimate the complete state of the system

Why DNSE+?

– combines both SCADA and PMU data to obtain the complete state of system; can provide synchrophasor output not available through PMUs
– mechanism to provide functionality to identify “bad” PMU data
– non-iterative;
– fast (executed at nearly phasor data rate); Challenge: huge systems of equations to be solved

Project Participants

Key team members

Executive Sponsor:
Damir Novosel

Quanta DNSE+ Project Manager
Dino Lelic

Department of Energy Project Manager
Brian Mollohan

EPG Project Team:
Wayne Schmus
Ashley Wang
Simon Mo
Iknoor Singh

Quanta Project Team:
Boza Avramovic
Tony Jiang
Vasudev Gharpure
Yi Hu

NYPA Project Team:
Bruce Fardanesh
Alan Ettlinger
George Stefopoulos
Saman Babaei

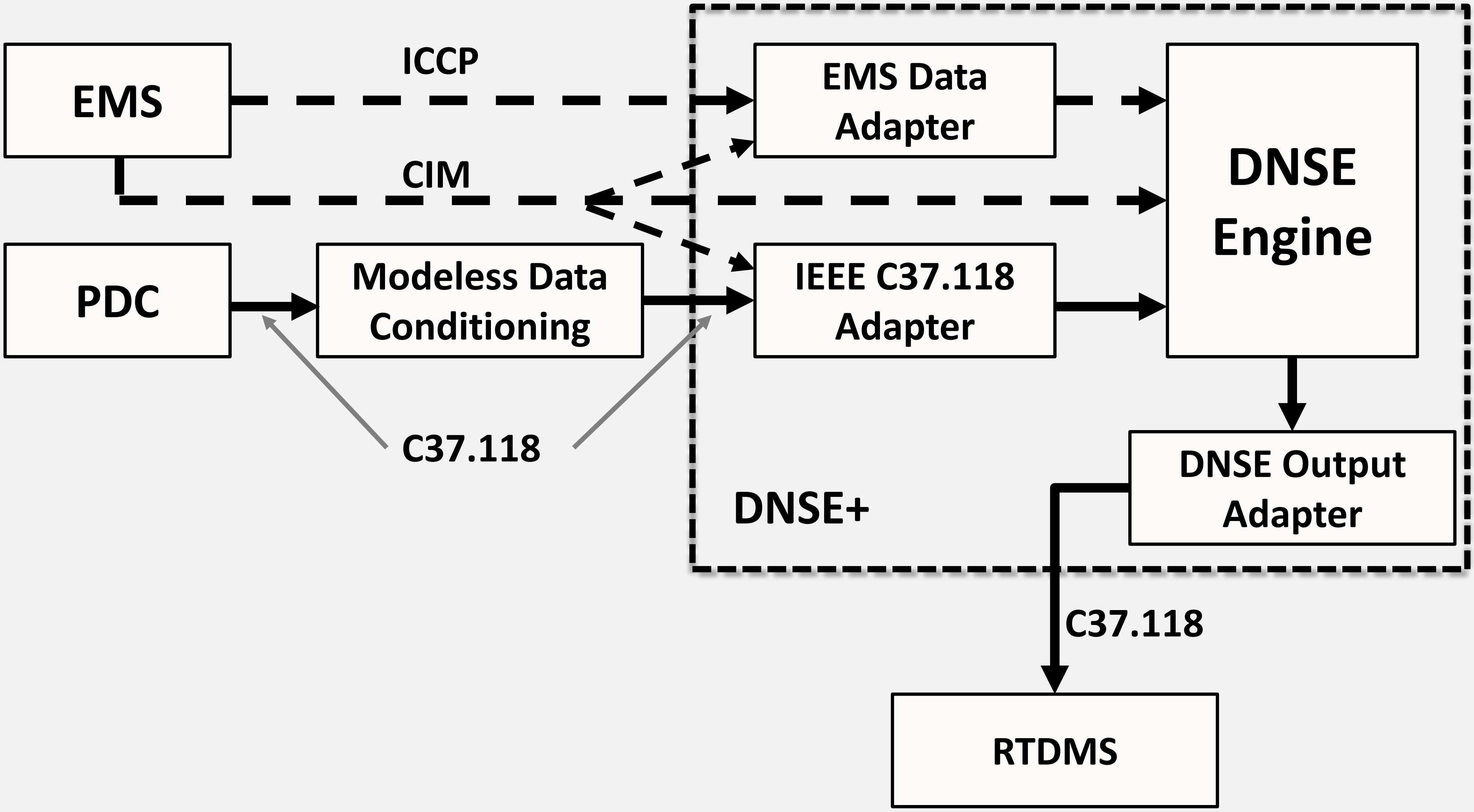
Project team Roles

- Quanta Technology
  - Overall project management
  - Overall technical lead; overall system design
  - System integration and FAT lead; Site Acceptance Test support
- NYPA
  - End user of developed system
  - System design support
  - Field installation & SAT test lead
- Electric Power Group
  - EPG product supplier
  - RTDMS enhancement development
  - System integration & FAT support
  - Field installation & SAT support

Project Accomplishements

- Successfully demonstrated DNSE+ at New York Power Authority (NYPA) that:
  - Used both SCADA and synchrophasor data simultaneously to obtain the complete state of the entire NYPA operating model at rates close to the phasor data rates, and without iterations.
  - Developed input/output adapters based on standards (IEEE 37.118 for streaming synchrophasor data, ICCP and SQL for SCADA exchange and CIM to export the host utility's EMS model data)
- Proved that DNSE+ is a commercially viable application by successful integration with commercial products (EMS and RTDMS)
  - RTDMS has been enhanced as part of the project
  - Enhanced C37.118-5 to include large data frames
  - Showed that DNSE+ is ready for use at other utilities to address a common need for "clean and trustworthy" operational data for synchrophasor applications

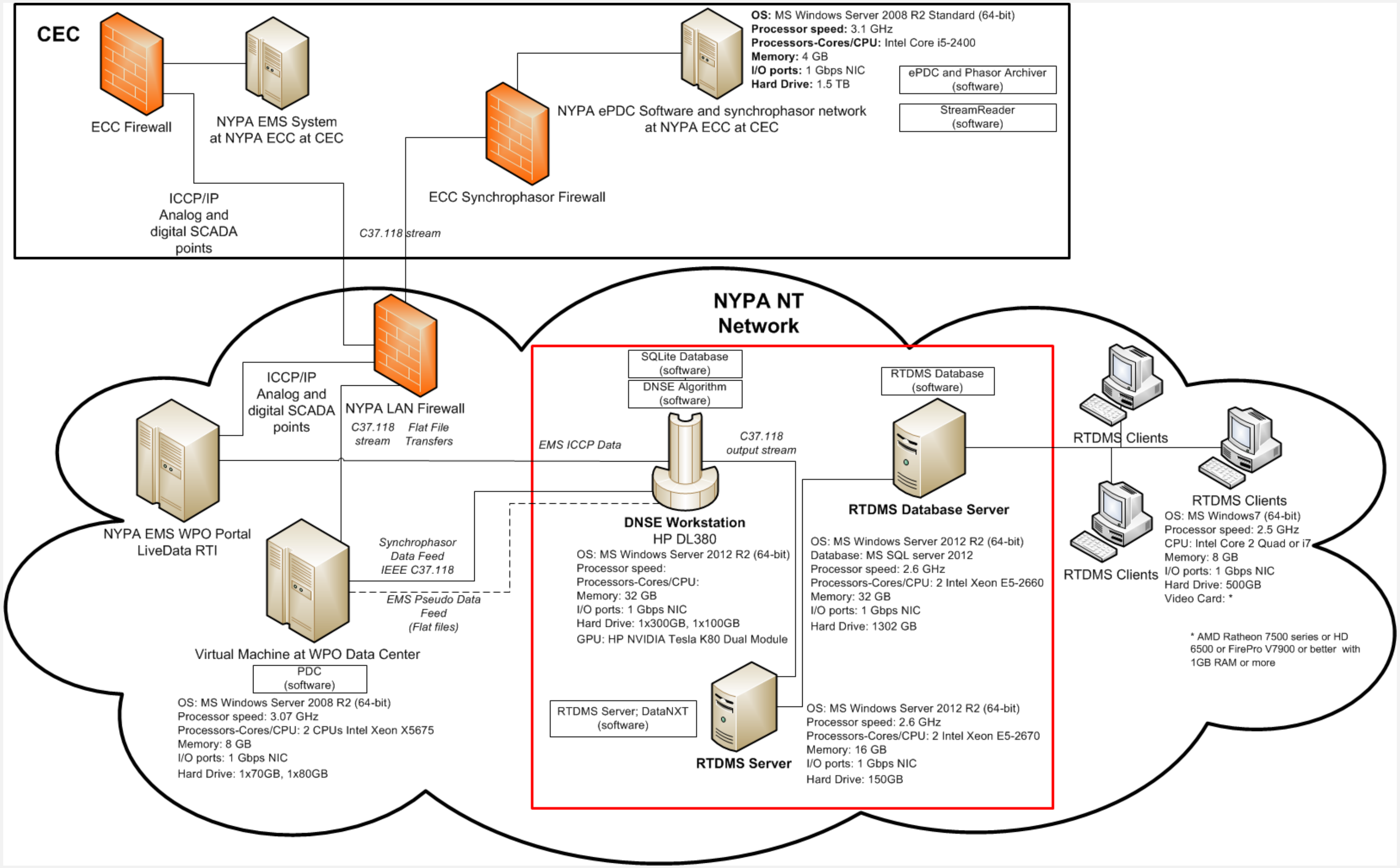
DNSE+ Conceptual System Architecture



DNSE+ Implementation Description

- Integration based on the NYPA EMS model, using live ICCP and PMU data
- Model consists of ~1600 network buses (~960 NY buses)
- The set of available live measurements:
  - 185 synchrophasor measurements
  - 4419 available SCADA measurements
  - About 3000 measurements utilized
    - 1250 digital statuses
    - 1717 analog measurements
      - 233 voltage magnitudes
      - 6 branch current magnitudes
      - 1244 P and Q flows
      - 188 P and Q injections
      - 46 Transformer taps
- Observable system of interest 150-200 buses
- NYPA EMS state estimator also utilizes about 2600 pseudo-measurements

DNSE+ System Architecture at NYPA



Synchrophasor Standard Extension - 1

- History:
  - Developed in 2000 – 2005 time frame
  - Devised for small systems envisaged then
  - Recent rapid adaptation and usage has revealed limits
- Configuration frame size limits
  - Useable long names addressed in 2011 update
  - Data frame size limit (65535 bytes) was not addressed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Technical Specifications

11/20/2014

IEEE C37.118.2-2011 Standard Extension

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Synchrophasor Standard Extension - 2

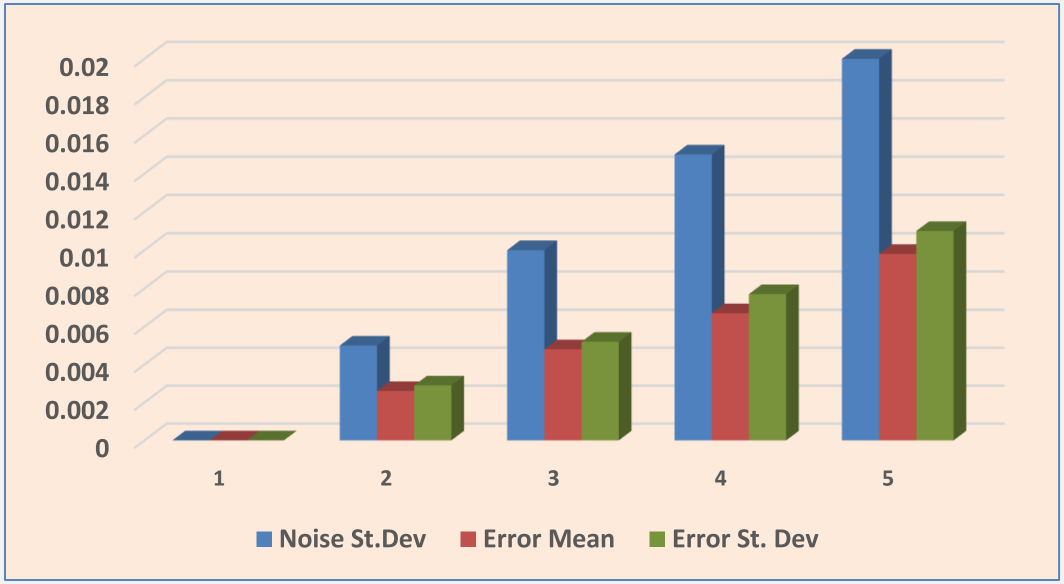
- Data Frame Extension During This Project:
  - Extended data frame specification – sends large data in multiple fragmented frames
  - Mostly based on capabilities already provided by the Standard
  - Implemented at data sender by QT, data receiver by EPG
- Data volume
  - ~8000 phasors

DNSE Engine – Test Results

Test 1: Add normally distributed noise to all measurements, and compare DNSE solution voltage to expected solution voltage. Noise is added as a percentage of measurement value.

- Results show DNSE has good error-rejection ability.

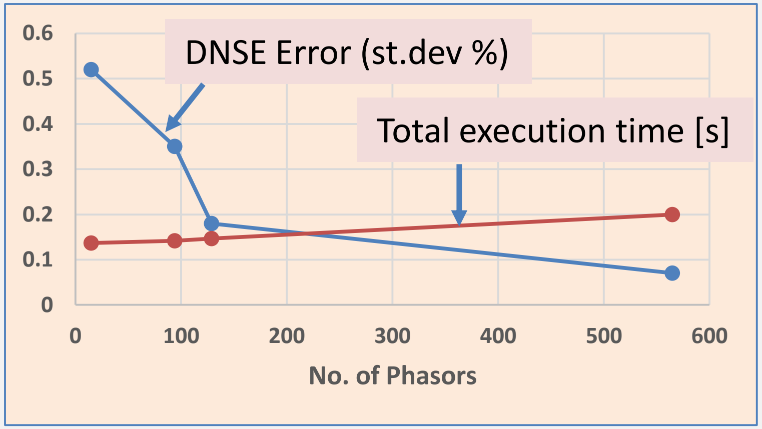
No.	Noise St. Dev	Error Mean	Error St. Dev
1	0	0	0
2	0.005	0.0026	0.0029
3	0.01	0.0048	0.0052
4	0.015	0.0067	0.0077
5	0.05	0.0098	0.011



DNSE Engine – Test Results

Test 2: Add more PMUs in NY area and evaluate performance

	Base	>= 345 kV	>= 230 kV	>= 115 kV
Voltage phasors	15	94	129	565
Current phasors	47	397	520	2015
Observable buses	148	276	309	752
Error Mean at 1% noise	0.0048	0.0025	0.0012	0.0006
Error st.dev. at 1% noise	0.0052	0.0035	0.0018	0.0007
Preproc. time: observ. analysis	0.1100	0.1000	0.1000	0.0800
DNSE sol. time (incremental)	0.0250	0.0400	0.0420	0.0700
Post.proc. time	0.0020	0.0020	0.0050	0.0500



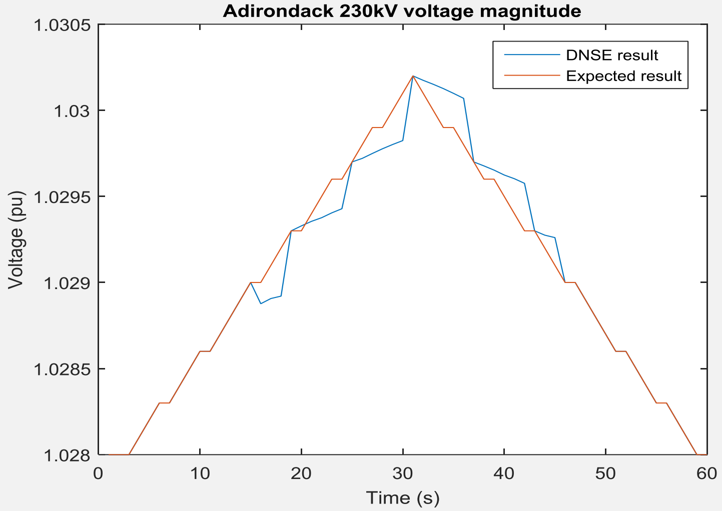
- Additional PMUs increase observability, and improve error rejection.
- DNSE observability analysis time decreases with more PMUs; DNSE solution time and post-processing time increases.

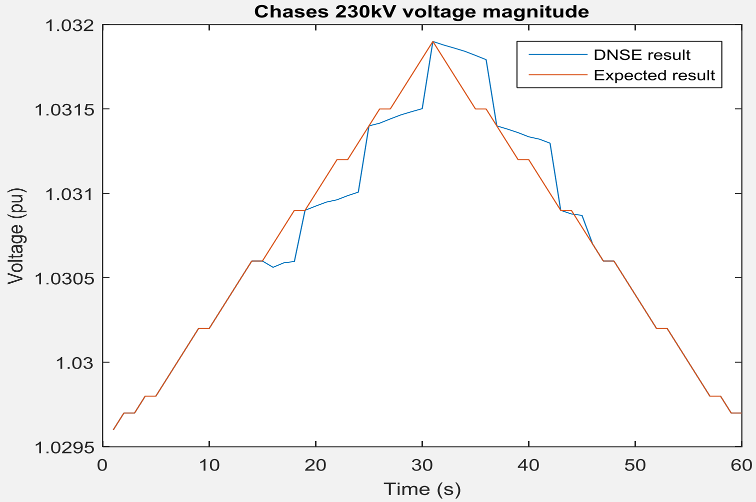
DNSE Engine – Test Results

Test 3: Drop phasor signals in the middle of an input data sequence to see change in observability and the DNSE solution.

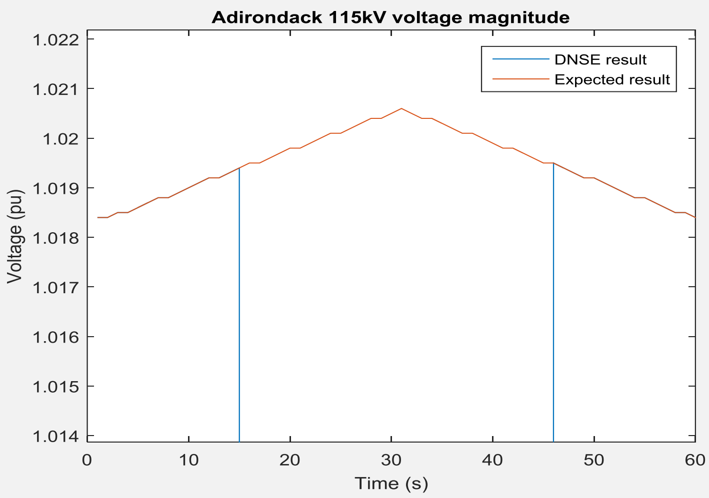
- Simulated data for 60 seconds. Phasor data refreshed once a second, and SCADA data refreshed once every 6 seconds.
- Simulation is of load in a zone ramping down and up.
- Drop PMU signals at Adirondack 230 kV and 115 kV stations, from t=16s to t=45s. “Chase 230 kV” is a non-PMU bus connected to Adirondack 230 kV.

DNSE Engine – Test Results





- Observability lost at Adirondack 115kV. DNSE output drops to 0 (unobservable) during PMU outage.



Future Implementations - Options

1. **A proprietary interface path:**
   - For situations without CIM, or
   - When EMS vendor has a fast SCADA bus, and wishes to interface using that bus
2. **If a utility EMS can export a validated CIM SCADA/EMS network model:**
   - Implement SQLite interface for SCADA data – relatively simple
   - Populate Metadata
     - Some EMSs already have metering information, including PMUs, modeled in their CIM – then a simpler task
   - Configure PMU input and output streams via configuration files
3. **Next Generation EMS:**
   - CIM is the source of DNSE models <u>and</u> Metamodel
   - SCADA bus used to provide SCADA data
   - “PMU bus” used to move PMU data to DNSE, and the results out of it.

NYPA experience in this project:

- Started from #1, implemented according to #2, plans under consideration for #3

Questions

Further questions? Contact: mlelic@quanta-technology.com