Use of PMUs for on-line power system security monitoring at ISO-New England

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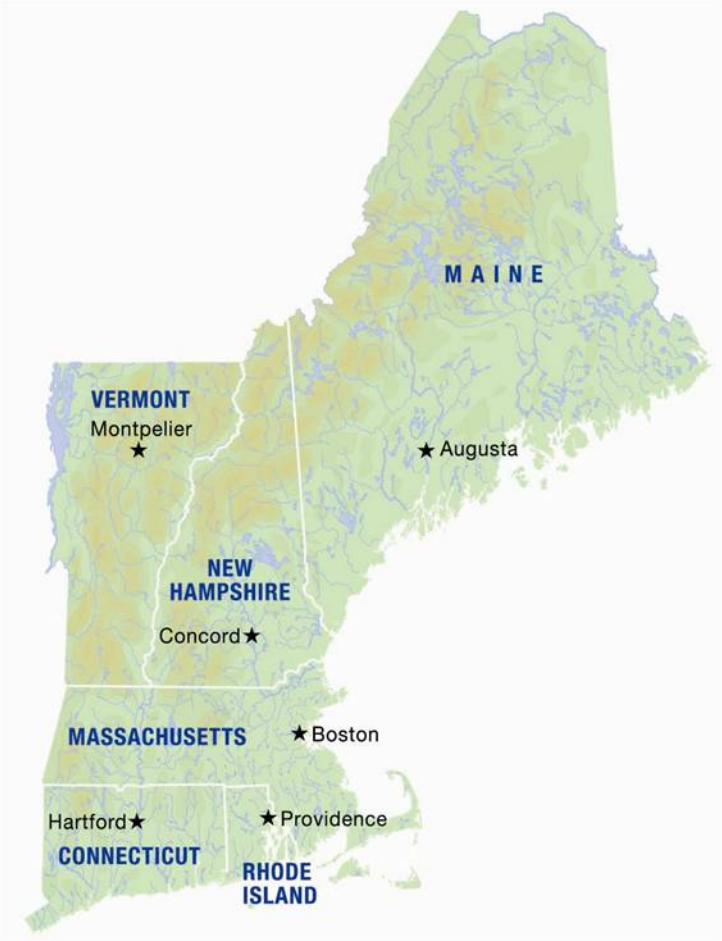
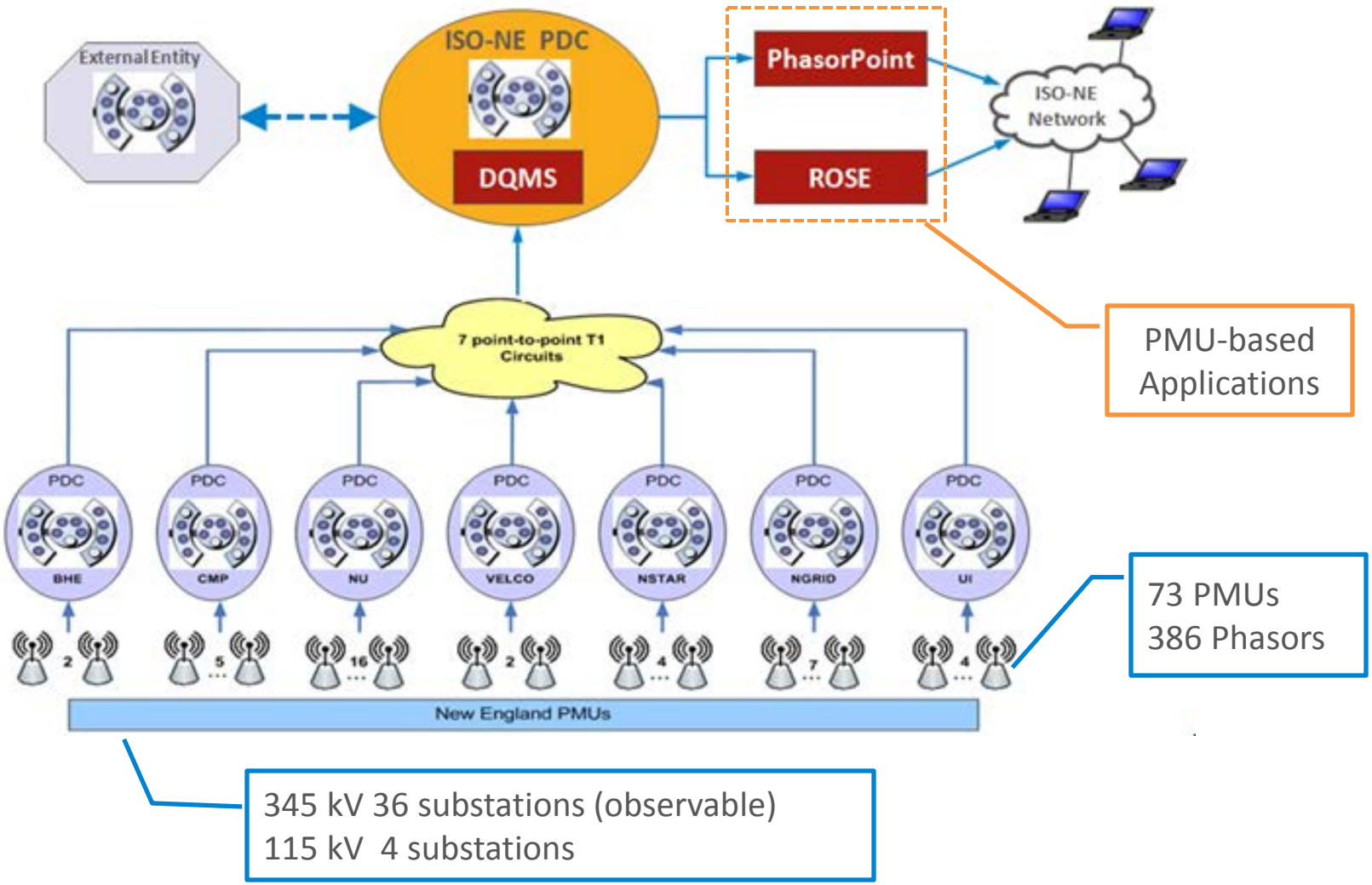
New England's Electric Power Grid at a Glance

- 6.5 million households and businesses; population 14 million
- 350+ generators
- 8,000+ miles of high-voltage transmission lines
  (115 kV and above)
- 13 interconnections to electricity systems in New York and Canada
- 31,750+ megawatts (MW) of generating capacity and approximately 1,850 MW of demand resources
- 28,130 MW all-time peak demand, set on August 2, 2006

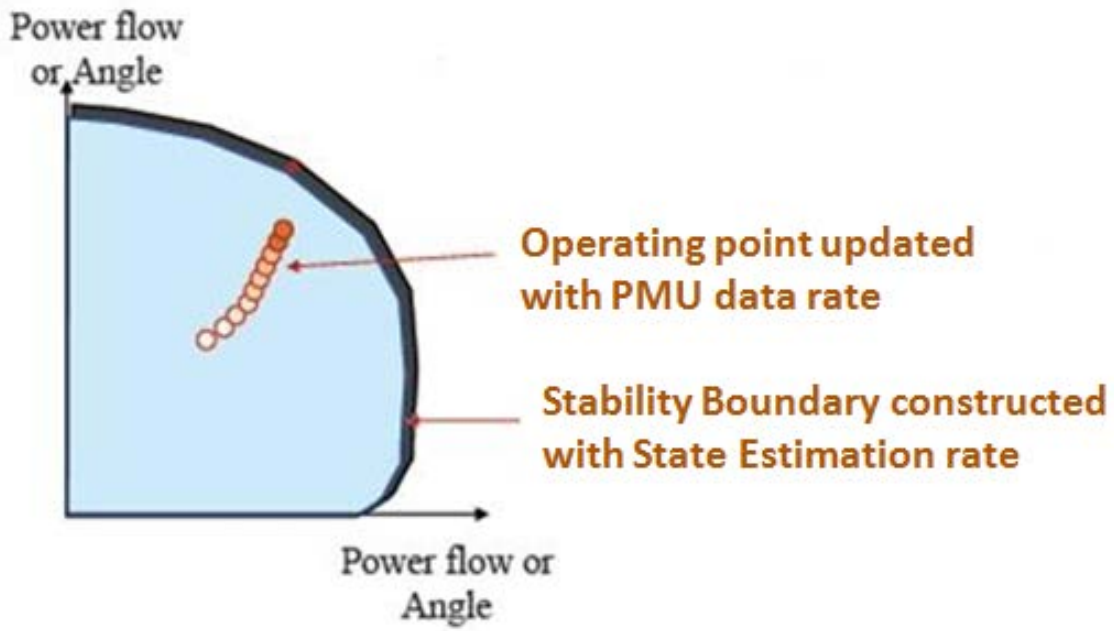


PMU Infrastructure at ISO-NE



Region Of Stability Existence (ROSE) concept

Objective: on-line tool for calculation of stability boundary and monitoring of power system security



Region Of Stability Existence (ROSE)

- State Estimation (model) is used to calculate ROSE boundary per N-k security criteria by observing the following criterion
  - ✓ Thermal overload
  - ✓ Voltage violation
  - ✓ Voltage stability
- PMU (measurements) are used to display current operating point and monitor Operational Margin.
- Vendor: V&R Energy System Research.

Application is currently used for engineering analysis and ISO-NE has developed a synchrophasor technology roadmap to migrate the technology into control room

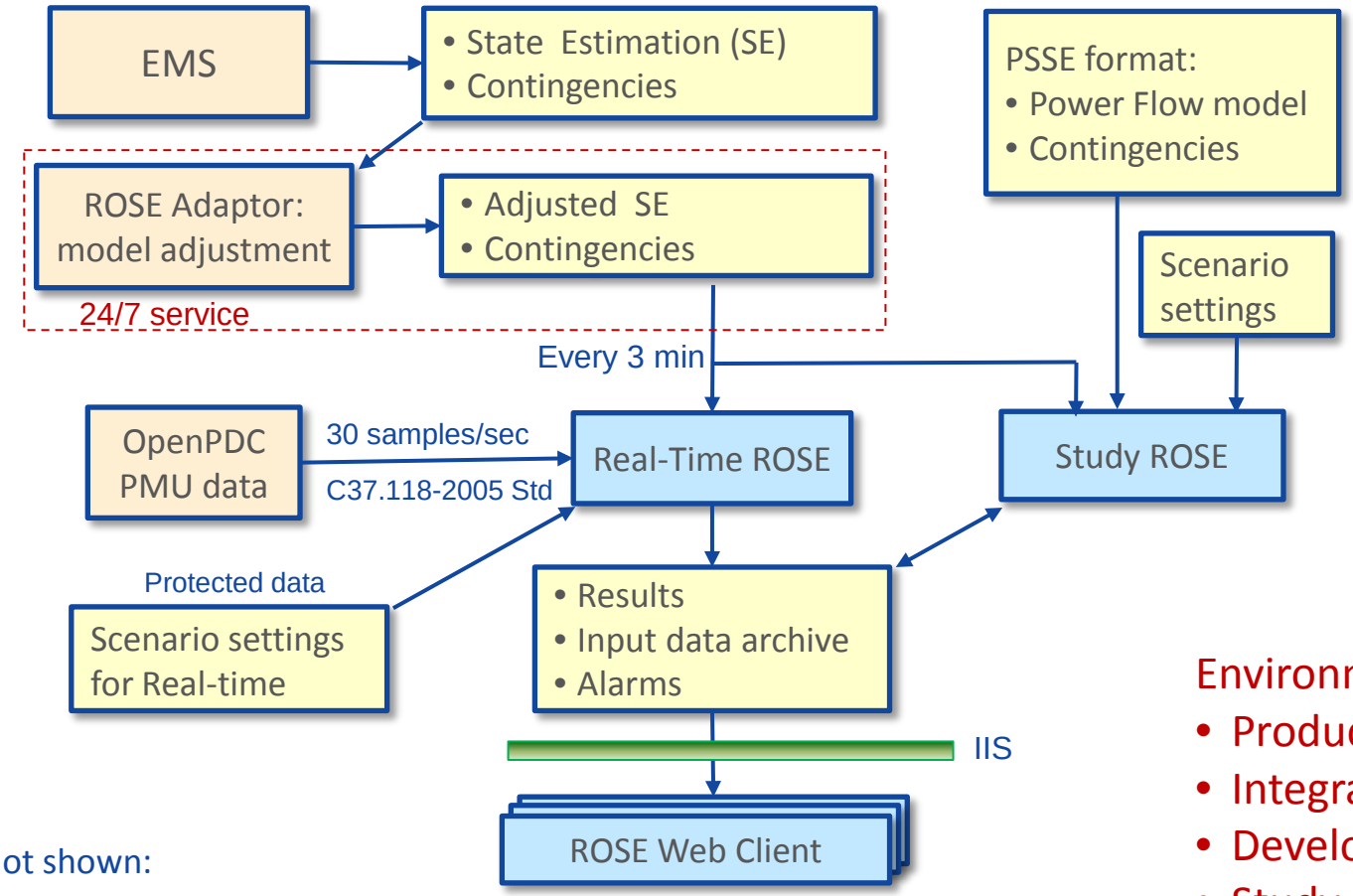
ROSE features

- Fast. Enables ISO-NE to perform power system security analysis for EMS model on-line for every State Estimation solution
- Develops corrective Remedial Actions to improve power system transfer capability
  - ✓ Switchable Shunts
  - ✓ ULTC
  - ✓ Phase Shifters
  - ✓ Generation MW and Mvar redispatch
  - ✓ Load shedding
  - ✓ Line switching
- Option to reports results in PMU bus angles

ROSE features, cont

- Multiple scenarios. One scenario is a PV-type of transfer study
- Generates alerts/alarms if security margin violates thresholds
- Topology Processing for EMS type of model
- Parallel processing
- Satisfies Cyber Security requirements
- Computing cycle for ISO-NE EMS model (15,000 nodes) including developing of Remedial Actions takes 30-60 seconds

ROSE Integration: Data Flow Diagram*



Environments:

- Production
- Integration
- Development
- Study

* Not shown:

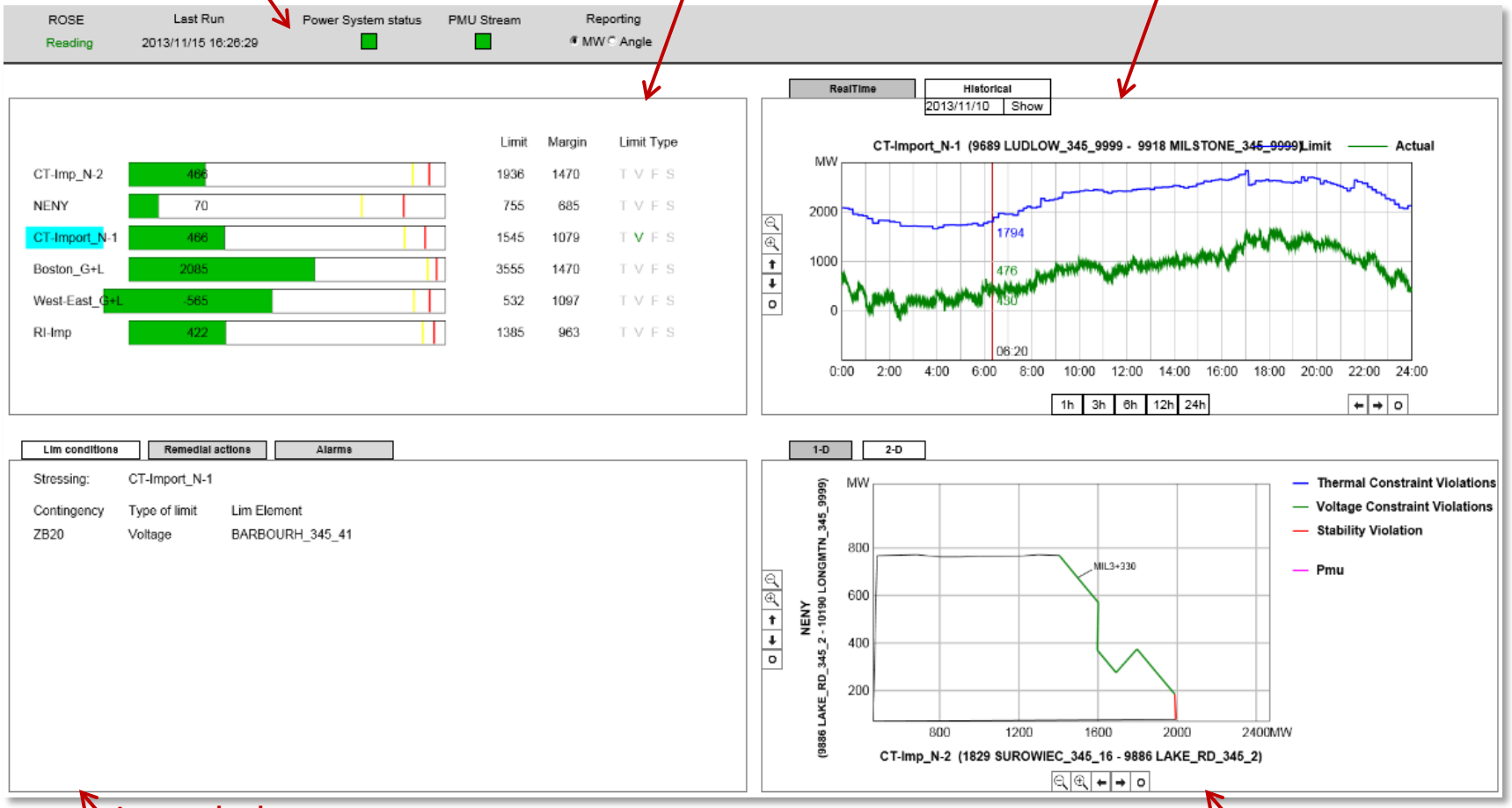
- Testing module with capability to stream historical PMU data and SE solutions
- Data purging service for archive

User interface to view results

RT security summary

RT security details

Trend plot: Historical results



Log window: Limiting conditions; Remedial Actions

3 min plot

Current use of PMU in ROSE

- PMU data reflect current operating point and trigger alert/alarm if Operational Margin (OM) violates pre-defined thresholds
- Bus voltage angles difference as a metric for OM
  - ✓ User defined pair of PMUs
  - ✓ ROSE advises on the most sensitive angle pair
- Intuitive approach: selecting pair of PMU angles across interface
- Off-line study of historical data to find angle pairs having high correlation with MW interface flow

Current use of PMU, cont

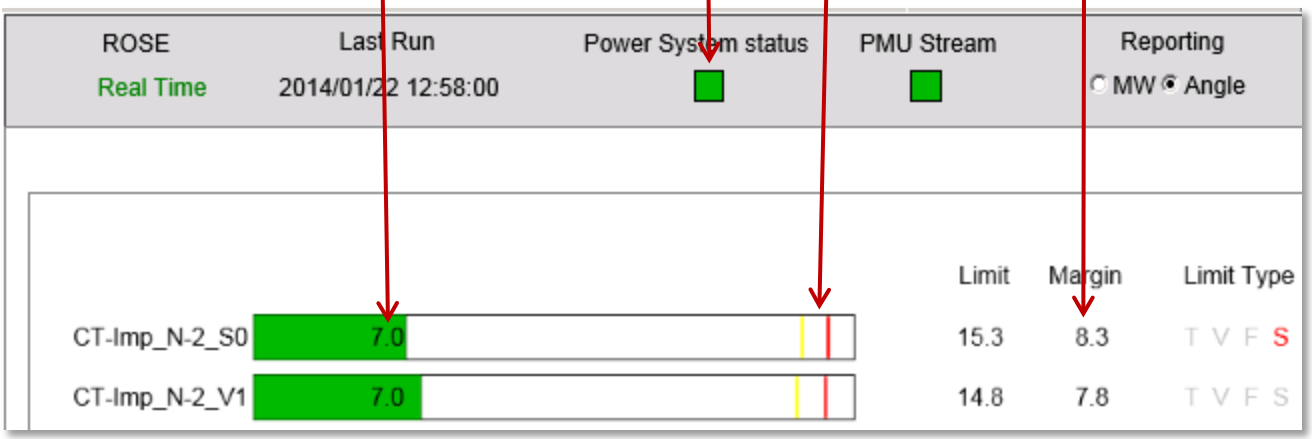
Shows the most severe violation of all calculated scenarios:

- – No violations
- – Alert threshold violation
- – Alarm threshold violation

Current angle

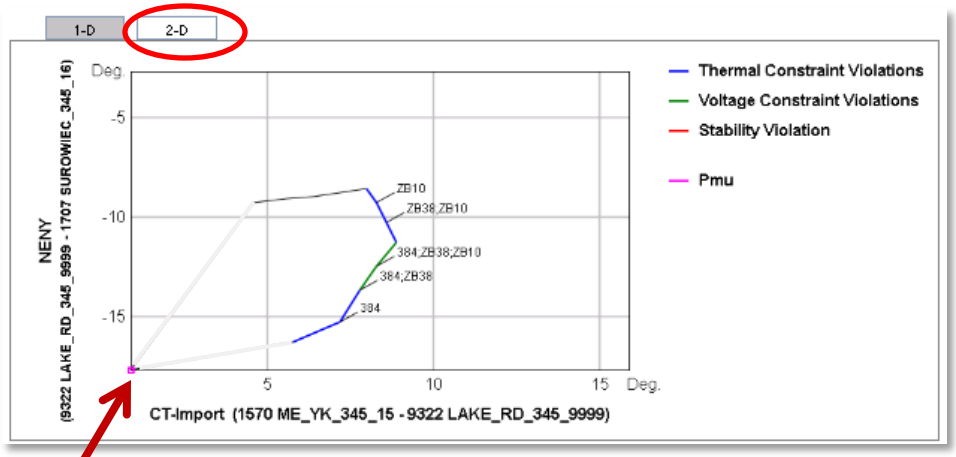
Alarm/Alert thresholds

Current Operational Margin

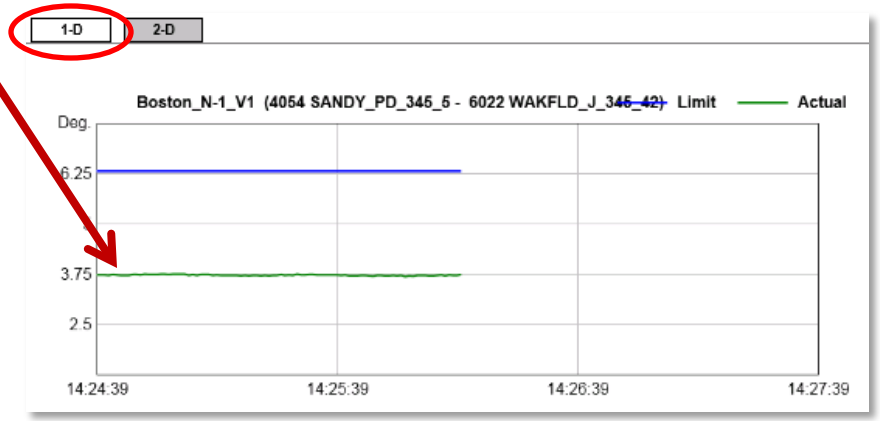


PMU angles to display Limits and current state

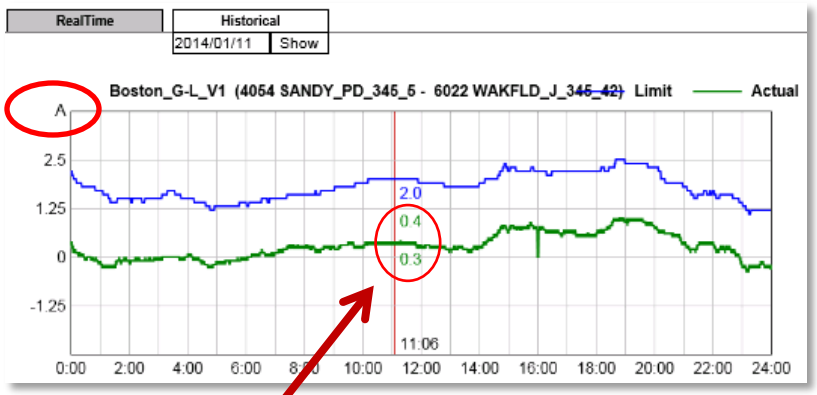
3-min plot: 1-D and 2-D veiws



Current state, updated every second



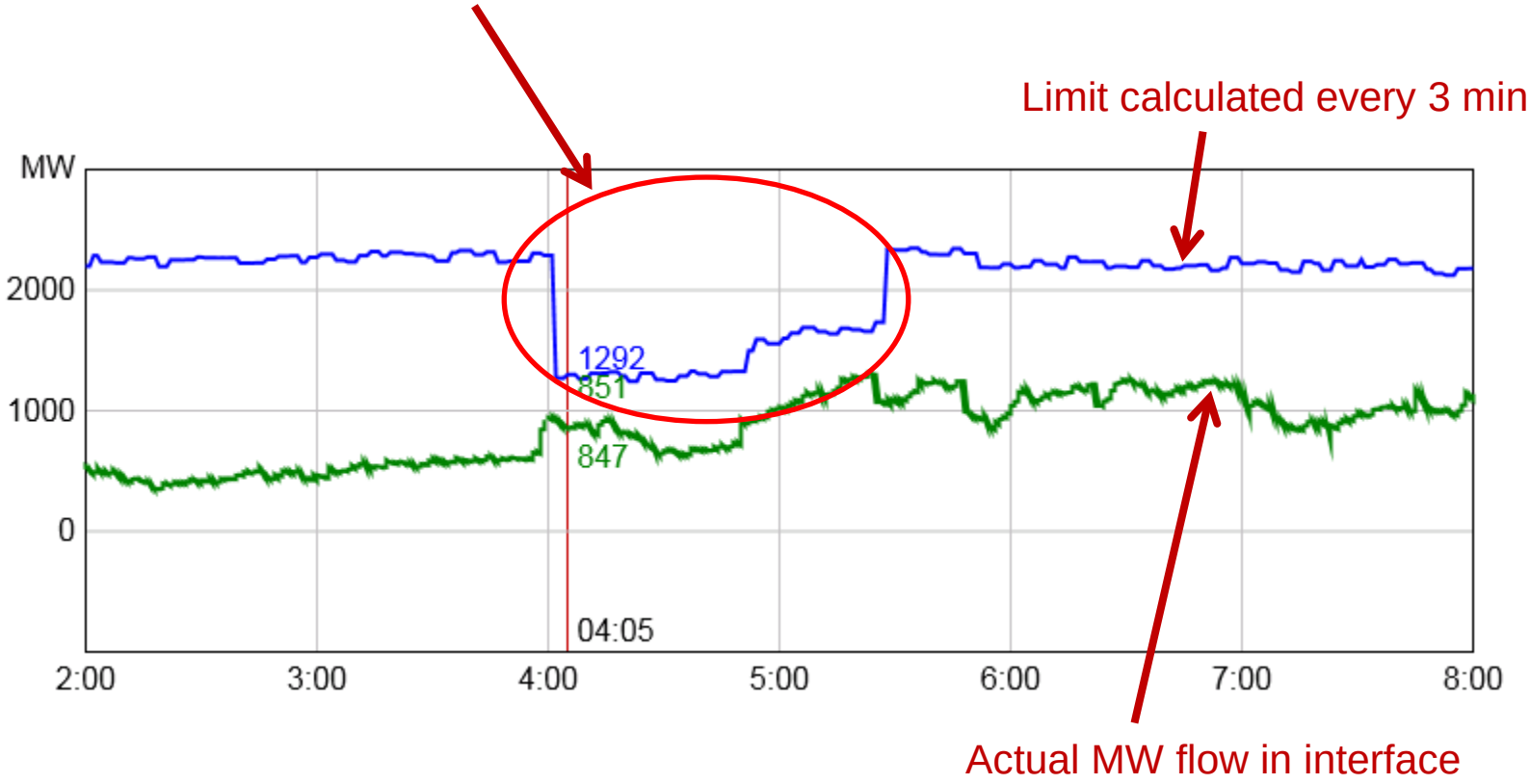
Trend plot: Real-Time and Historical



Accumulated Max/Min values within1 minute

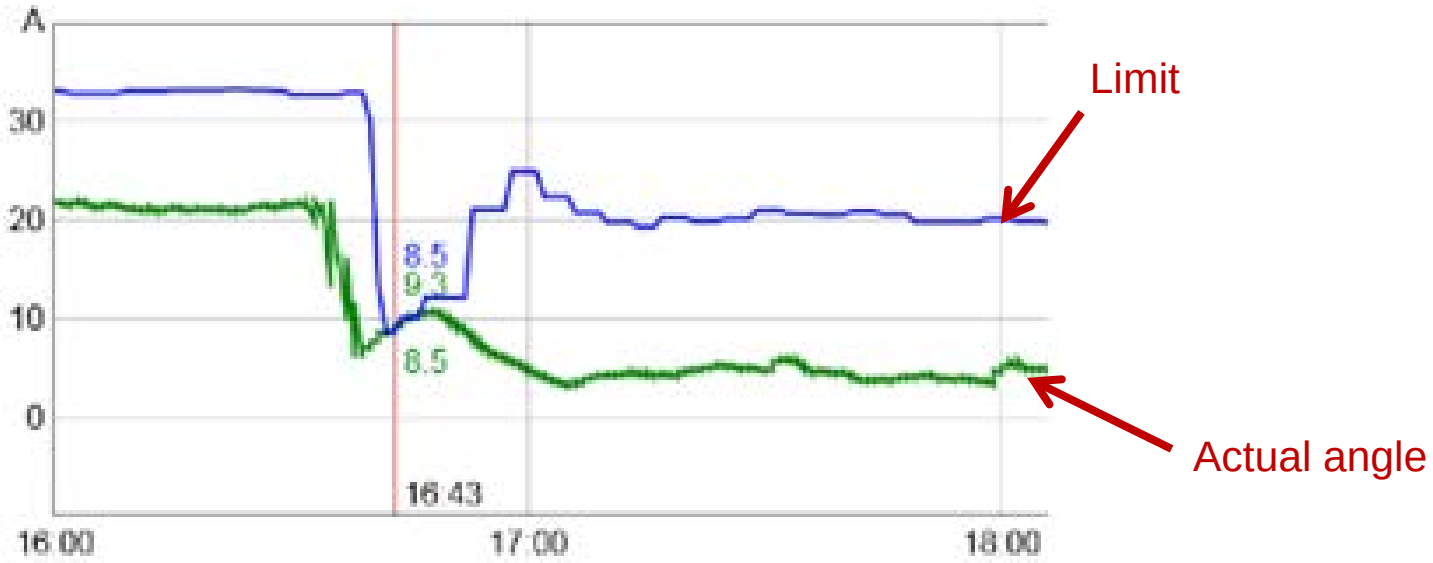
Real-Time event

Reduction of NY-NE interface limit for 1.5 hour due to operation of large hydro pumping station



Real-Time event, cont.

- Loss of 1500 MW due to trip of both poles of HVDC at Sandy Pond
- CT-Imp limit expressed in Degrees as Angle across interface

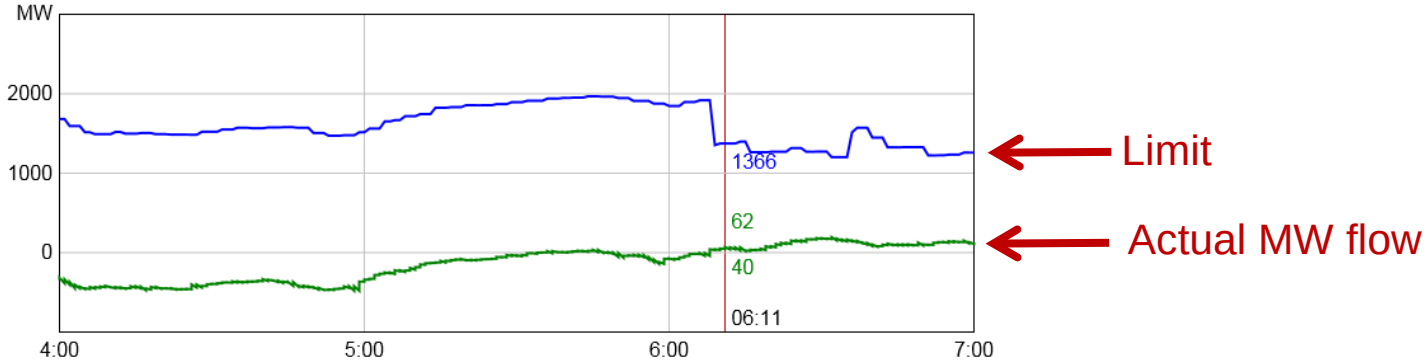


Line tripping events

- CT-Imp interface limit per N-2 security criteria

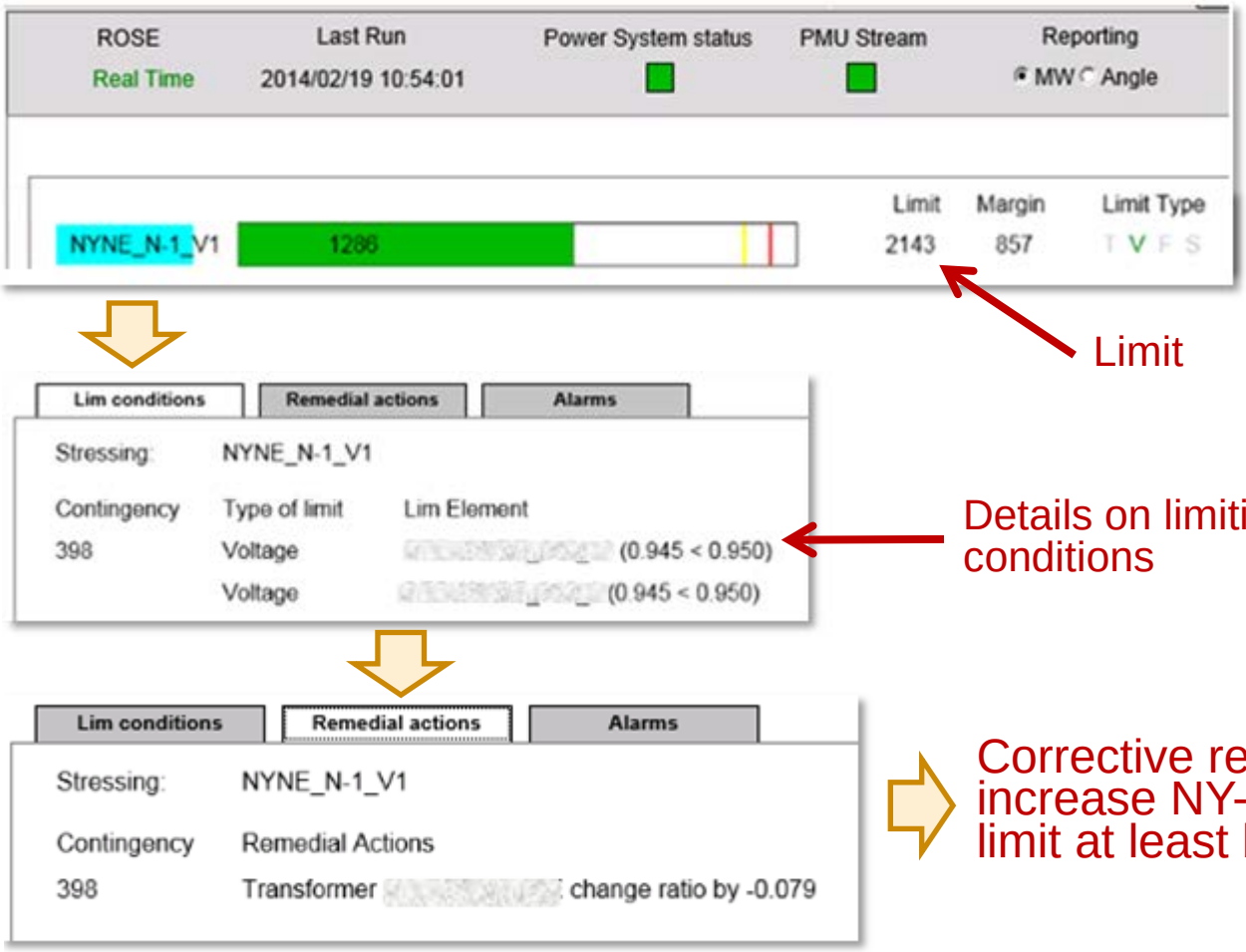
Limit as angle across interface

Limit as MW flow



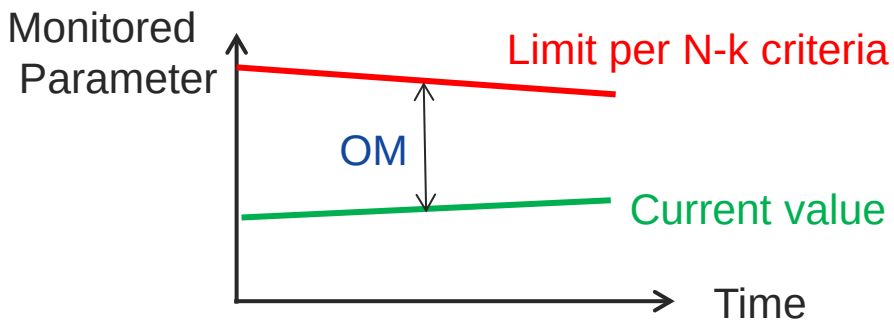
Corrective Remedial Actions (RA)

- Recommendations for RA provided for every scenario



Challenge – selection of Monitored Parameter

- Operational Margin (OM) is a measure of security
- Monitored Parameter (MP) is a metrics for OM



- Can PMU based MP be better than traditional MW flow?
- What exactly does it mean – better?
- How to design “good” MP?

Requirements for Monitored Parameter

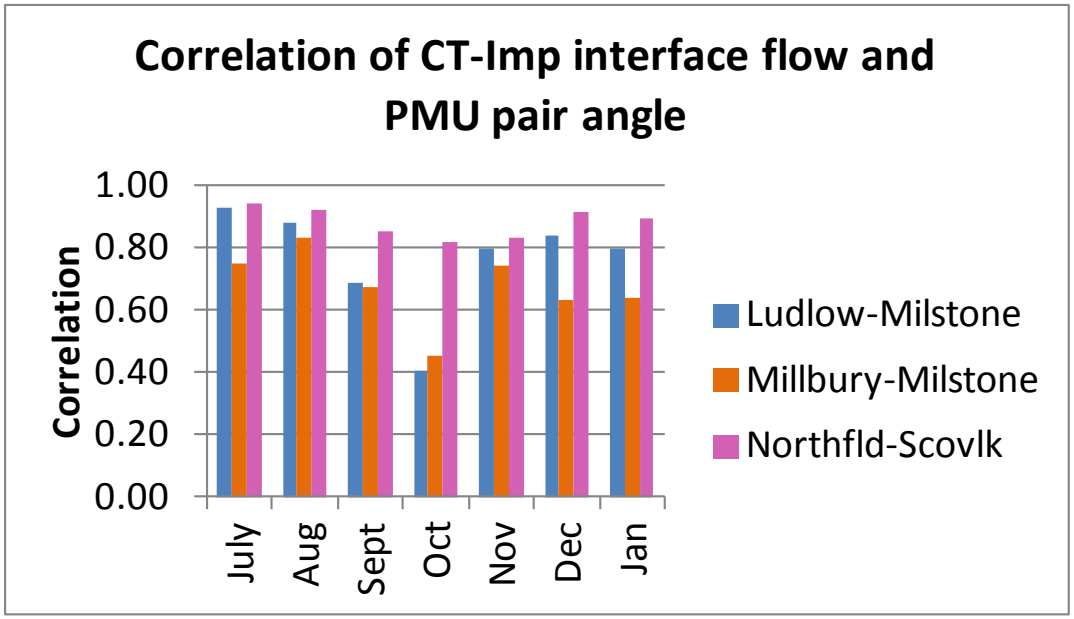
For use by Operators in Control Room

- Convenient for human perception
  - ✓ The same definition of MP over time
  - ✓ Traceable; no sudden jumps of MP value at small variation of operating conditions
  - ✓ Minimal OM threshold should be consistent over time
- Should not provide misleading OM value after sudden change of operating state before new limit is calculated

Difficult to satisfy simultaneously all these requirements

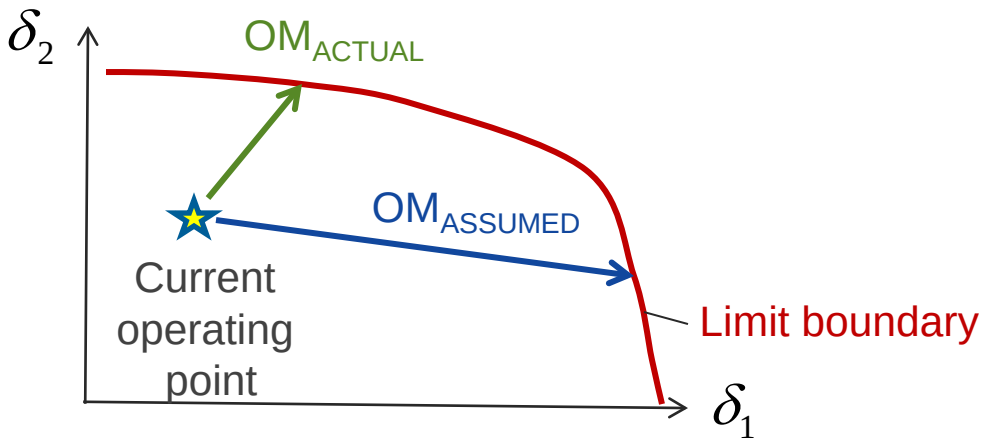
Interface flow – Angle correlation

- It is common sense that the use of any angle across interface as MP is similar to use of MW flow in interface
- Not so simple – different angles have different correlation with MW interface flow
- Correlation changes over time



Challenge - System stressing in Limit calculation

- Assumed angle change in modeling should be similar to the actual to avoid big errors



Need to use SCOPF-based system stressing for limit calculation to mimic actual system dispatch

Conclusions

- ROSE application has been successfully deployed at ISO-NE and demonstrated the efficiency for on-line power system security estimation and monitoring
- Use of PMU in ROSE enables fast and accurate tracking of operating point and security margin
- Application is used by engineers today and ISO-NE has developed synchrophasor technology roadmap to migrate the technology into control room

Questions