Improving Real-Time System Performance and Reliability by Using Synchrophasor Data

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1. About V&R Energy

V&R Energy

- V&R Energy's services include:
  - Comprehensive software tools for analyzing power system behavior
  - Advanced consulting services
  - Cutting edge scientific research
- V&R is located in Los Angeles, CA

*I'm convinced you (plural) are **the only ones in the industry** giving the proper thought and attention to the problems that transmission operators and planners are trying to manage*

- American Transmission Co.

*V&R Energy's software allows us to **do in 20 minutes** what normally takes about **seven hours** with our present system*

- East Kentucky Power

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V&R Energy Customers

Recent V&R Energy's Awards

- **V&R Energy has been awarded a contract to supply our PMU-based voltage stability analysis software, ROSE, to WECC under the Western Interconnection Synchrophasor Program (WISP), December 2011.**
- **V&R Energy has been awarded a contract to supply ROSE to ISO New England Synchrophasor Infrastructure and Data Utilization (SIDU) Project, 2010**
- **DOE Award: "20% Wind by 2030: Overcoming the Challenges", 2010**
  - Improving Reliability of Transmission Grid to Facilitate Integration of Wind Energy in Tri-State G&T and AECI
- **NYSERDA Award, 2010**
  - Prevention of Occurrence of Major Catastrophic Events: Demonstration for Con Edison System

2. The Region Of Stability Existence (ROSE)

Fast, Robust and Accurate Analysis

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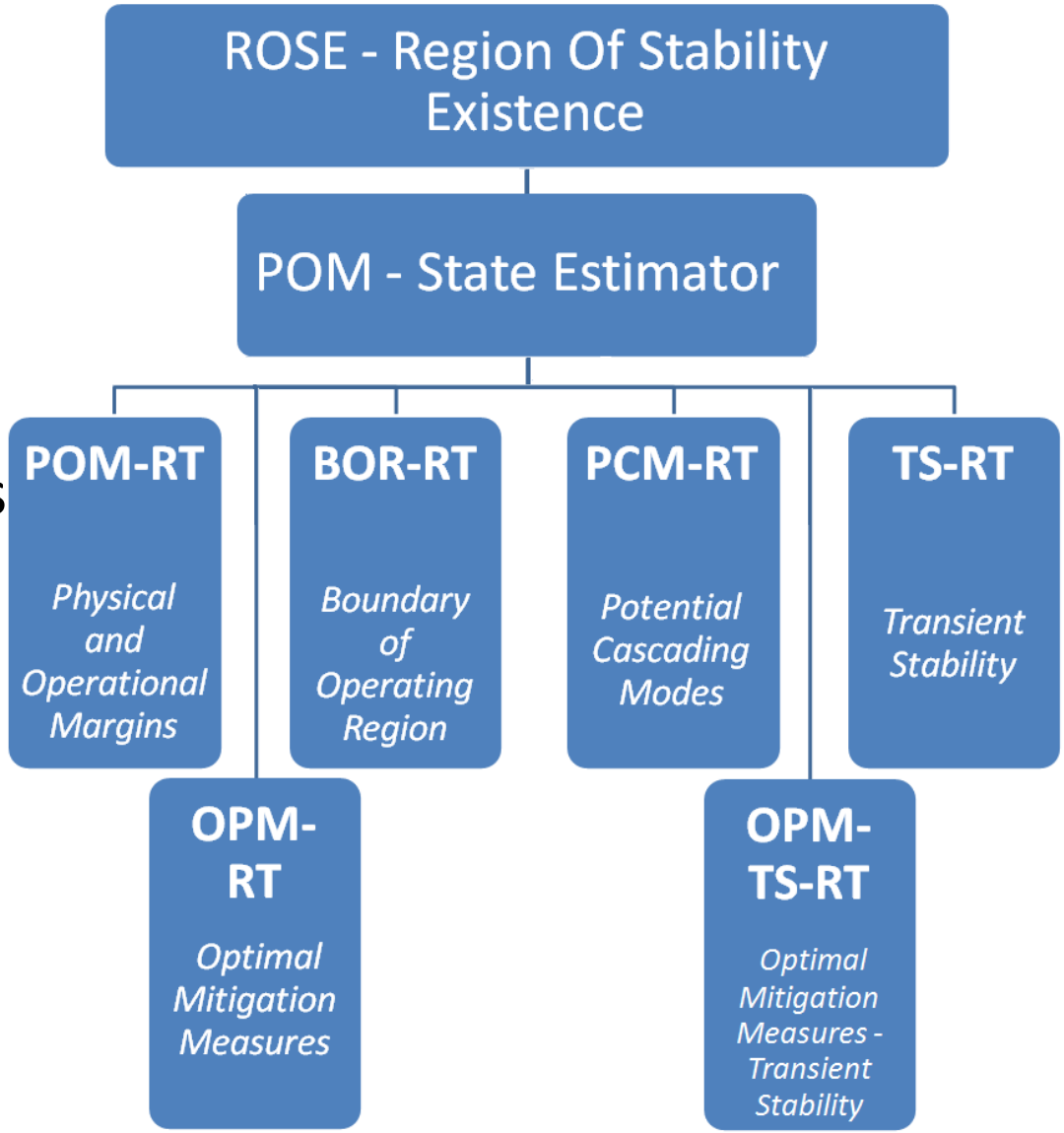
What is ROSE?

- *Region Of Stability Existence - ROSE* defines the range of phasor measurements or other system parameters
  - For which the system may securely operate in terms of the accepted N-k security criteria
- Addresses the problem of utilizing the PMU data to increase the situation awareness of the operators and improve stability and reliability of the electric grid
  - For steady-state analysis: voltage stability, voltage constraint (voltage range and/or pre-to post contingency voltage drop) and thermal overloads may be simultaneously monitored, enforced and visualized on the boundary

ROSE Application Framework

- Same algorithms for off-line and real-time analysis
- Model-based & measurement-based State Estimator
- Integrated voltage and transient stability analyses
- Boundary-based solution
- Automatic analysis of cascading outages
- Automatic remedial actions to mitigate steady-state & transient stability violations



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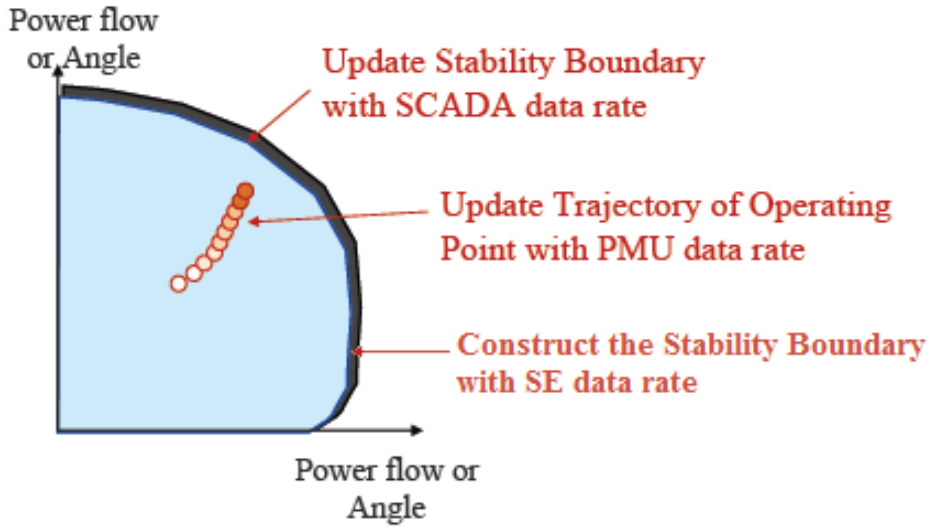
Utilizing PMU Data to Make nearly Instantaneous System Operational Decisions

- *ROSE* uses PMU and State Estimator data for on-line calculation and visualization of the current operating point and its proximity to the stability boundary
  - Additionally, SCADA data may be used to update the boundary



Figure, see http://ewh.ieee.org/reg/1/809/Litvinov.pdf.

- Relationship between the current operating point and the boundary defines "health" of power system network state:
  - Each point on the boundary corresponds to a "nose" point on the P-V curve, or a thermal or voltage constraint being violated

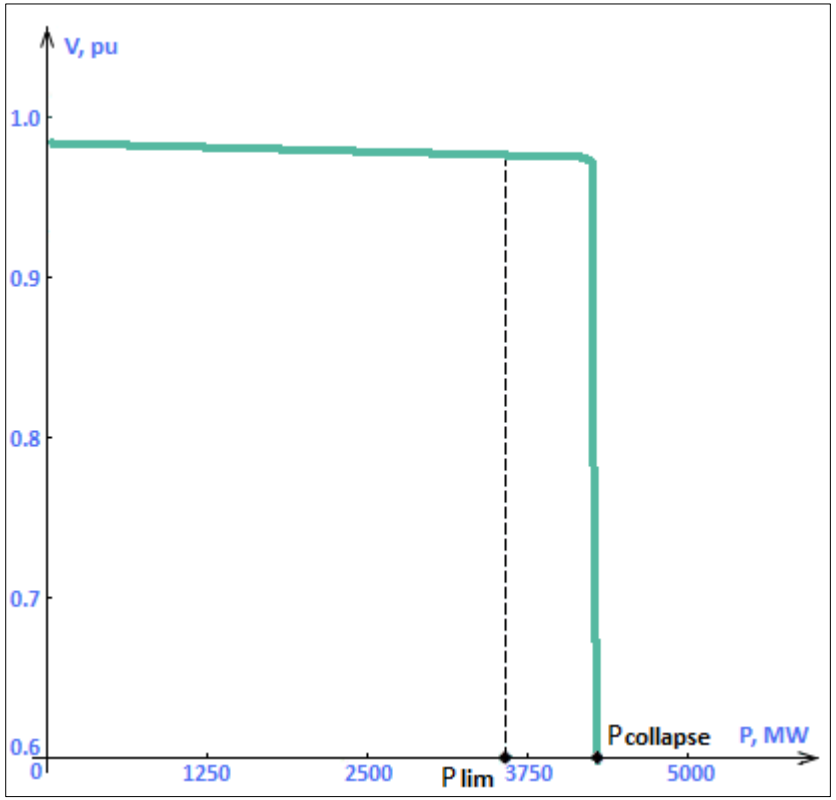
Use of PMU to Identify Steady-State Stability Limit

- *ROSE* provides the framework for utilizing PMU measurements in order to:
  - Improve state estimation;
  - Continuously monitor the electric grid:
    - Identify system stability limits under normal and contingency conditions;
    - Alarm the operator about the impending crisis before a new State Estimator (SE) case arrives;
    - Invoke optimal remedial actions to prevent a blackout.

ROSE "Hybrid" Approach

- *ROSE* is based on the hybrid approach:
  - Current operating point is computed used the synchrophasor data;
  - The boundary (e.g., limiting conditions) are computed using the model data (State Estimator case).
- PMUs do not provide predictive capabilities:
  - PMUs accurately show the current state;
  - The use of an accurate, robust and fast model-based approach is essential for correctly identifying the real-time limits and computing the boundary.

Advanced Voltage Stability Analysis: Case of a "Flat" Voltage Profile



- Since measurements only or traditional PV-curve analysis do not always predict the impending collapse, operators can't take any control actions to prevent the collapse until it is too late:
  - Advanced analytics is needed
- Transmission system starts to exhibit the changes (point P_{lim}) which would eventually lead to voltage collapse (point $P_{collapse}$)
  - ROSE can identify P_{lim}

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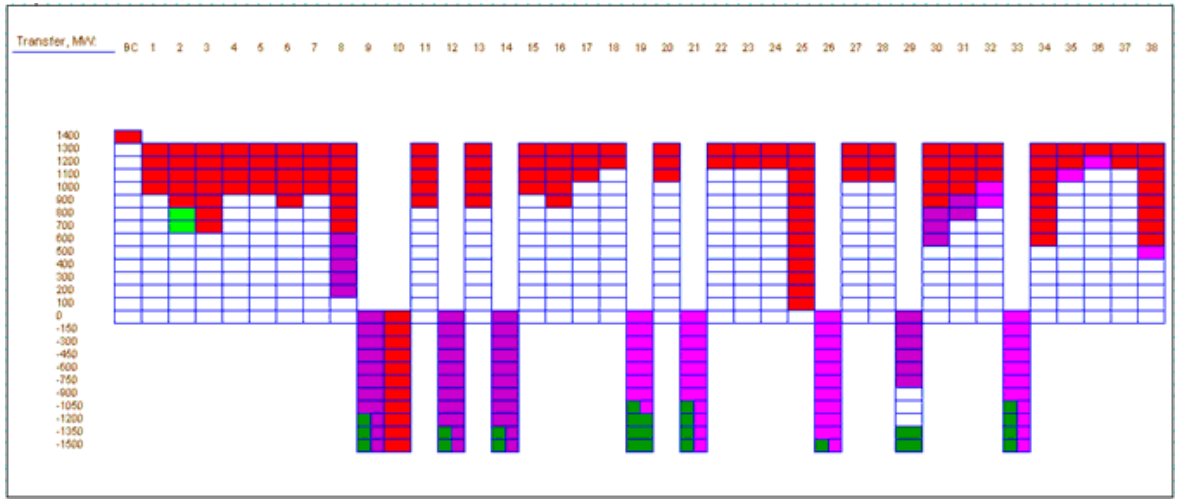
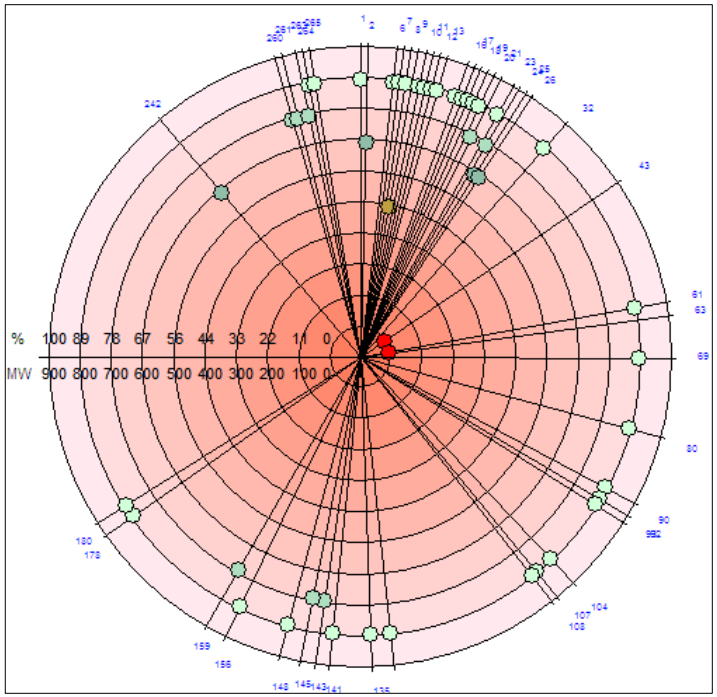
Computing System Stability Margins

- System stability margins under N-1, N-2 contingency conditions





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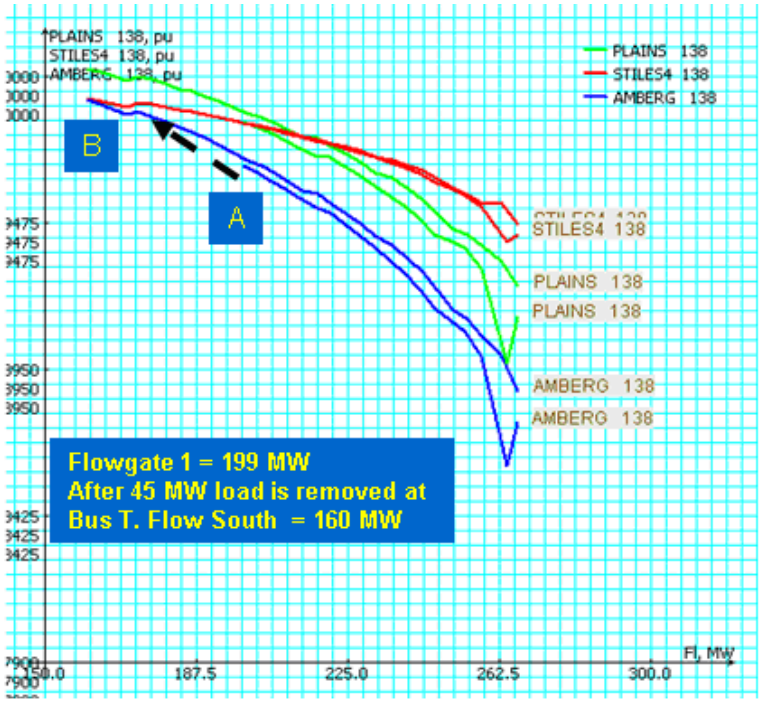
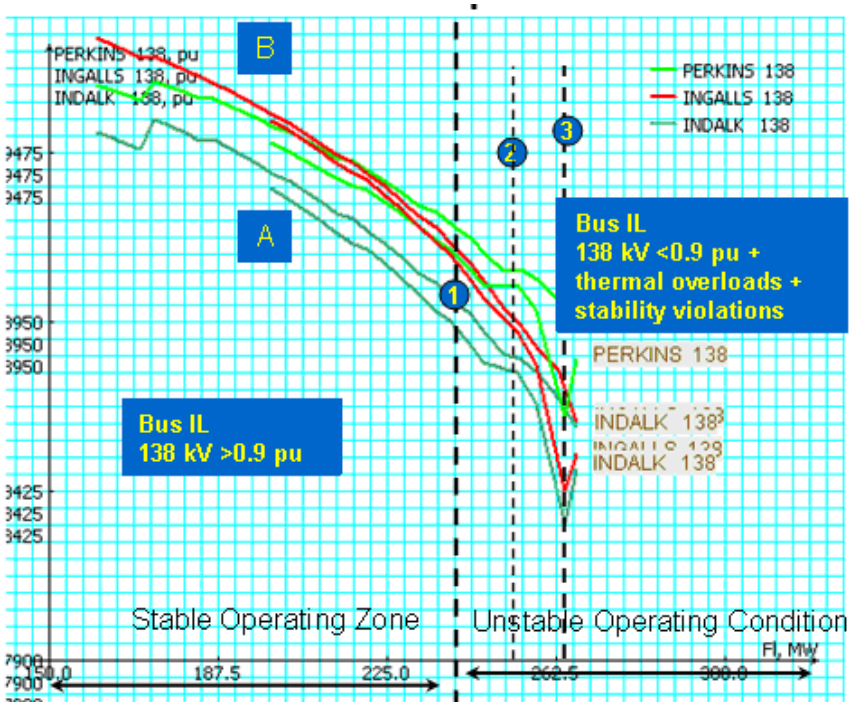
PV- Curve Analysis

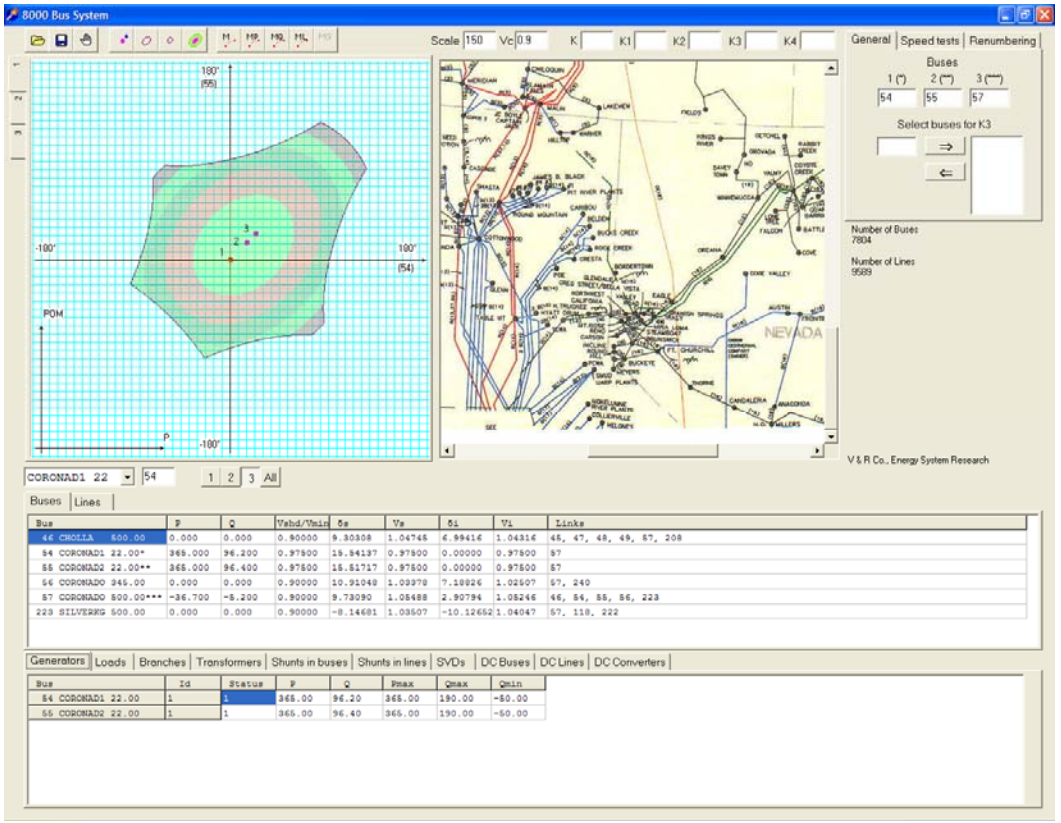
- Used for interfaces in the power system that are sensitive to voltage collapse
  - Then, operating limits are established
- Quickly re-evaluate the limits as system conditions change





Alarming the Operator

- An operator is alarmed if the operating point and the boundary are moving towards each other in terms of:
  - MW/MVAr/MVA margin across the interface or load pockets



- For multiple PMU installations, *ROSE* identifies two most critical phase angles, and displays the current operating condition and the boundary on the plane of the most critical phase angles and other user-defined parameters

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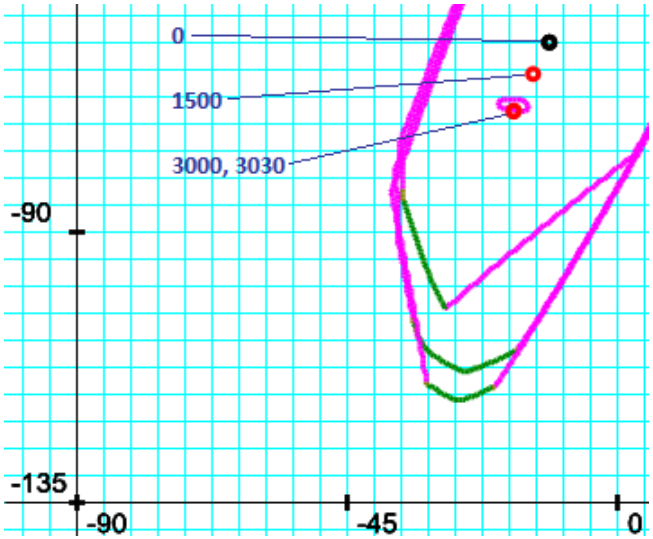
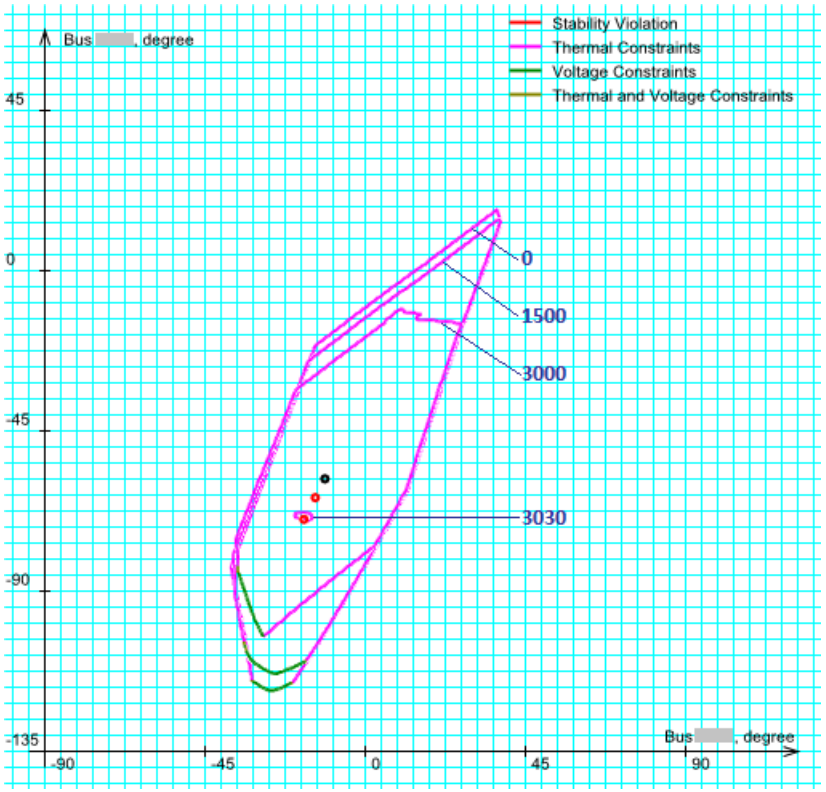
Preventing System Collapse

- If the operating point and the boundary are moving towards each other, **automatically identify (recommend to the operator) minimal optimal preventive actions before the new SE case arrives** and before the system collapse
- Available optimal mitigation measures are MW, MVAR re-dispatch, ULTC settings, phase shifter settings, switching CAP banks, line switching, load curtailment
- Identifies two types of measures:
  - Corrective measures for each contingency
  - Preventive (global) measures for all contingencies

ROSE Boundary for the Base Case and Stressed Conditions

- **Automatically identifies the limit in real-time**
- Shown on the plane of phase angles
- Base case is indicated as “0”
- At the limit value of stressing
  - The boundary degenerates
  - The operating point lies on the boundary





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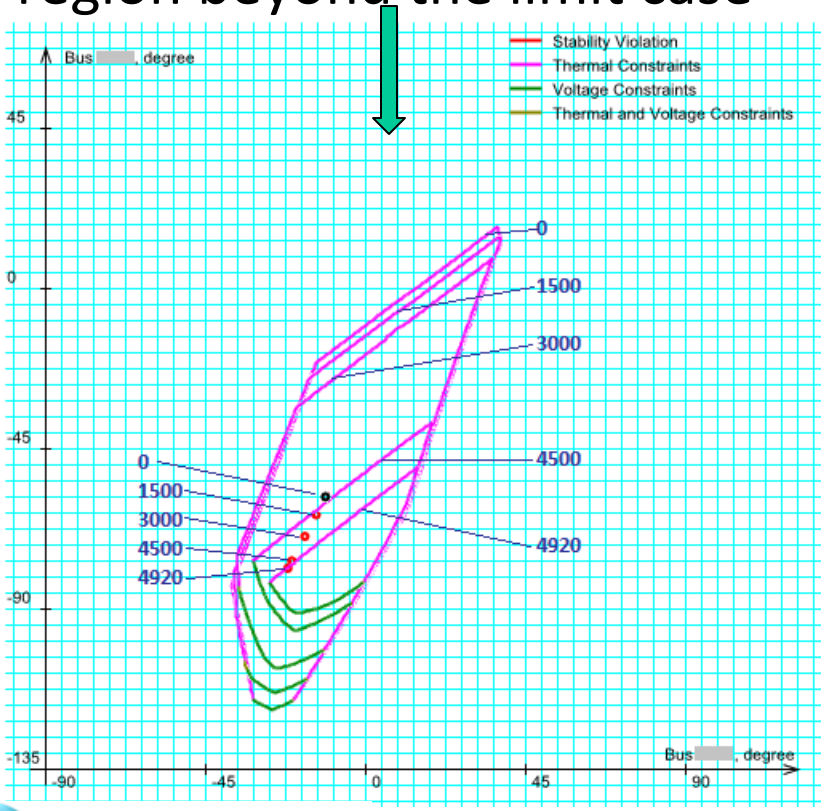
Use of Remedial Actions

- The effect of remedial actions on increasing the boundary for the limit case
- Using remedial actions to increase the region beyond the limit case



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Conclusion

- *ROSE* increases situational awareness of the operators by allowing them to accurately and timely predict steady-state instability and compute system stability limits in real-time environment by using phasor quantities collected by PMUs
- *ROSE* offers continuous monitoring of the system conditions under normal and contingency conditions using PMU data
- *ROSE* computes the limits based on the model data
- *ROSE* alarms the operator before a new State Estimator case arrives
- *ROSE* automatically identifies optimal mitigation measures for the use by the operators in order to prevent collapse