# ROSE - Calculation and Visualization of Power System Stability Margin Based on PMU Measurements

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# 1. About V&R Energy

## Smart Team for Smart Solutions

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# 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

# 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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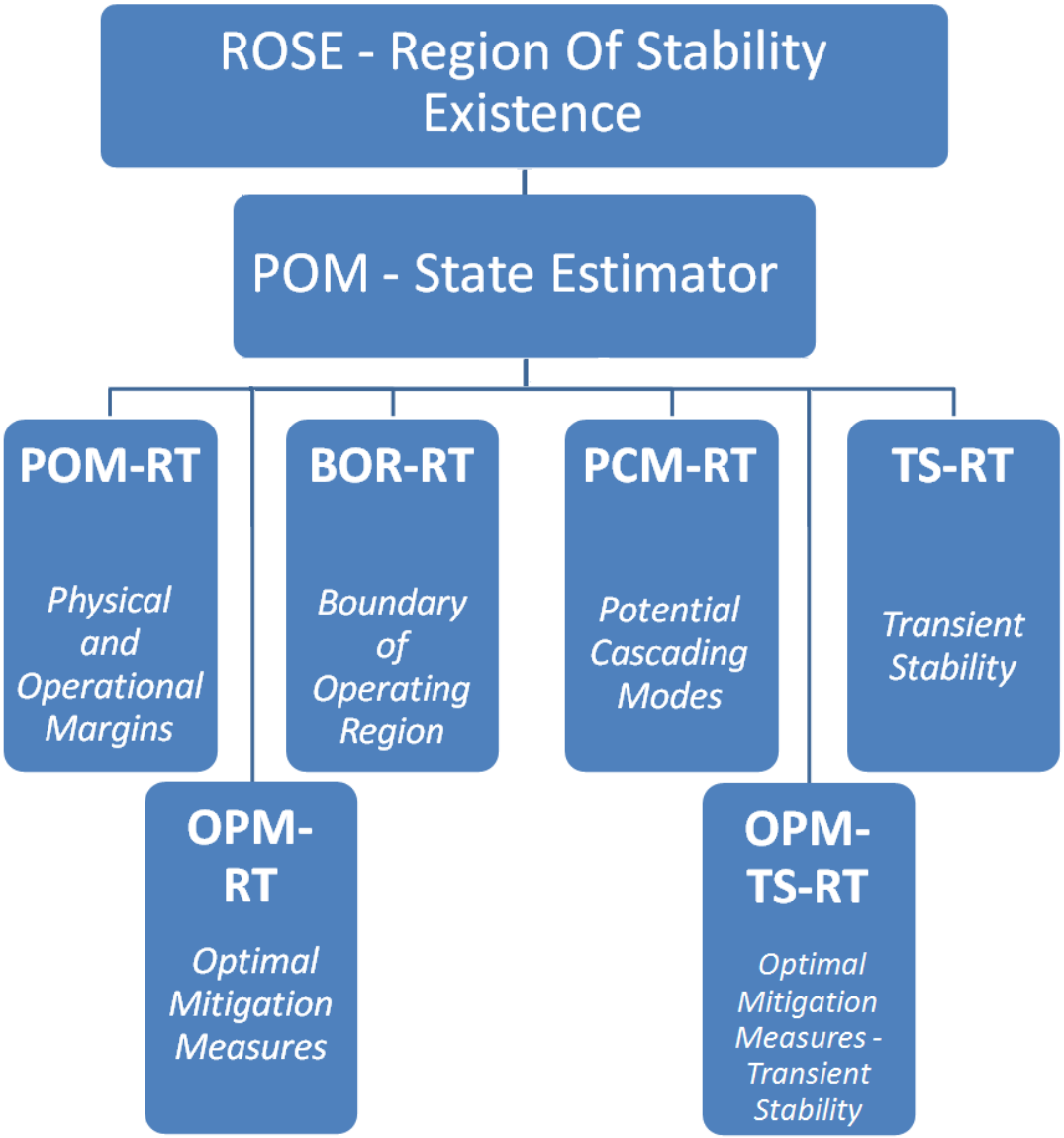
# What is ROSE?

- *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 situational 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 Applications

- 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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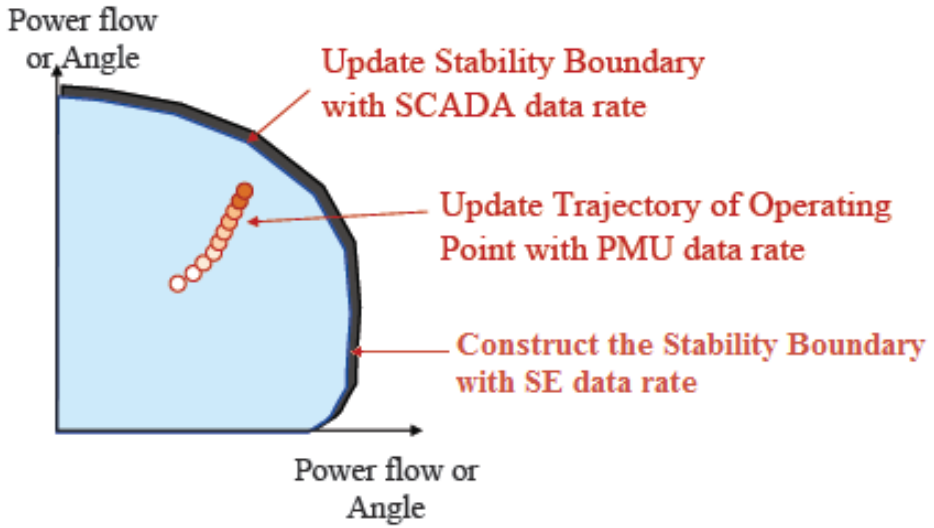
# Utilizing PMU Data to Make nearly Instantaneous System Operational Decisions

- *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

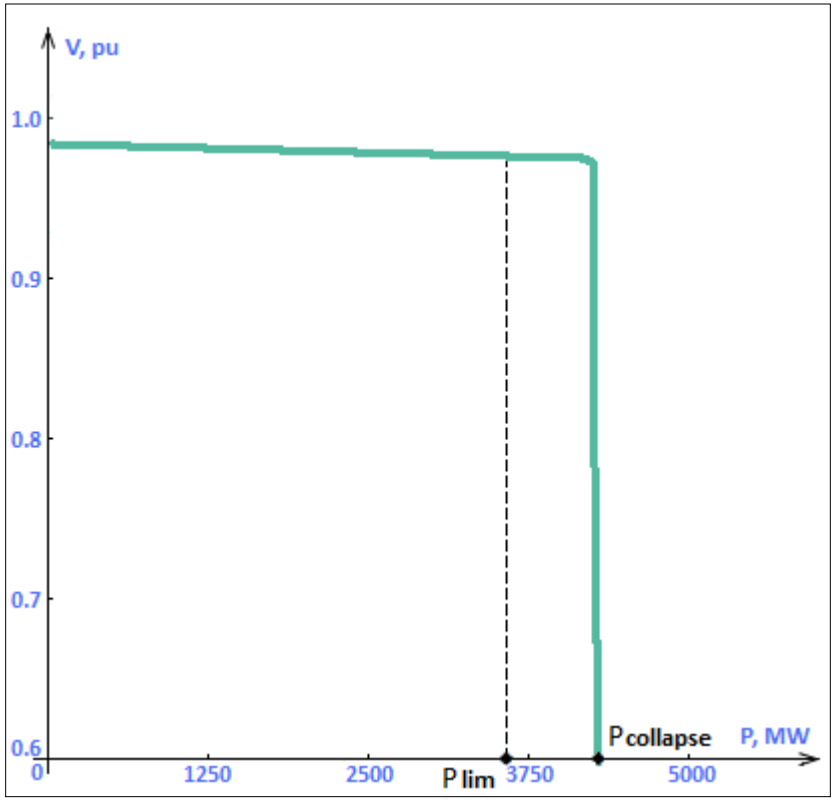
# Use of PMU to Identify Steady-State Stability Limit

- *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.

# What ROSE Does and Does NOT Do

| This is what ROSE Does | This is what ROSE NEVER Does |
|---|---|
| ROSE DOES Fast, Accurate, Robust Computations | ROSE NEVER DOES Any Simplifications |
| Voltage stability analysis is an extremely complex task, and ROSE treats it as such | Never does equivalencing, such as system representation as a two-bus equivalent circuit |
| Uses robust State-Estimator and State Measurements | Does not use any "simple" algorithms: |
| Performs extremely fast computations: about 10 times faster than other applications | In voltage stability analysis<br>SIMPLE = SIMPLIFIED<br>and SIMPLIFIED analysis leads to misleading results and incorrect alarms |
| Uses AC Solution for steady-state stability and contingency analysis, cascading outages analysis | NEVER leaves the user with the trade-off between the accuracy of computations and their speed |
| Accurately represents operation of all control devices in the network | Never computes limits off-line, and then visualize the current operating point vs. off-line limits |
| Performs fast time-domain simulation for transient stability analysis | |
| Automatically determines remedial actions to increase operating margins due to voltage and transient stability limitations | |
| Performs automatic analysis of cascading outages | |
| Provides a boundary-based solution with steady-state and transient limits on the boundary | |
| Predicts collapse when measurements only or PV-curve analysis do not indicate imminent collapse (see plot on the next slide) | |

# 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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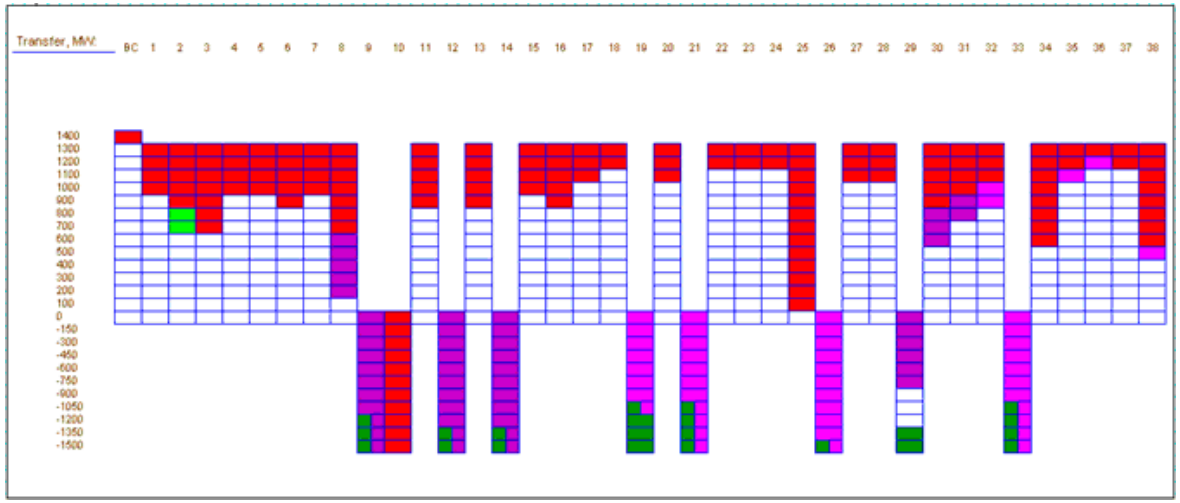
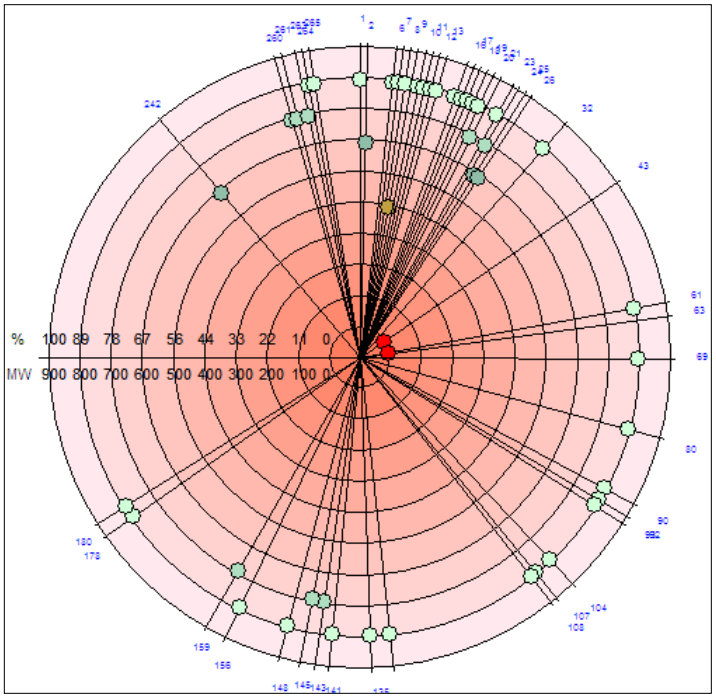
# Computing System Stability Margins

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

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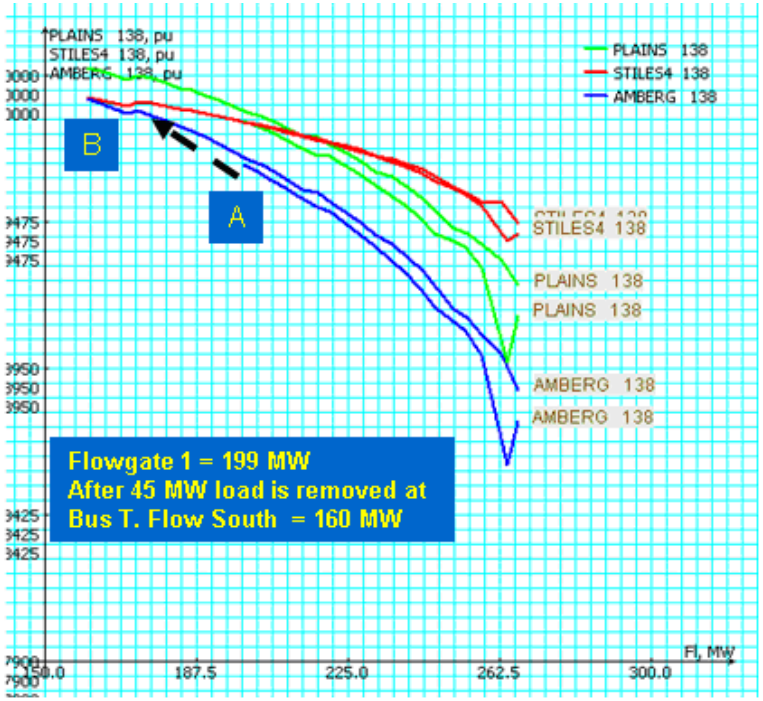
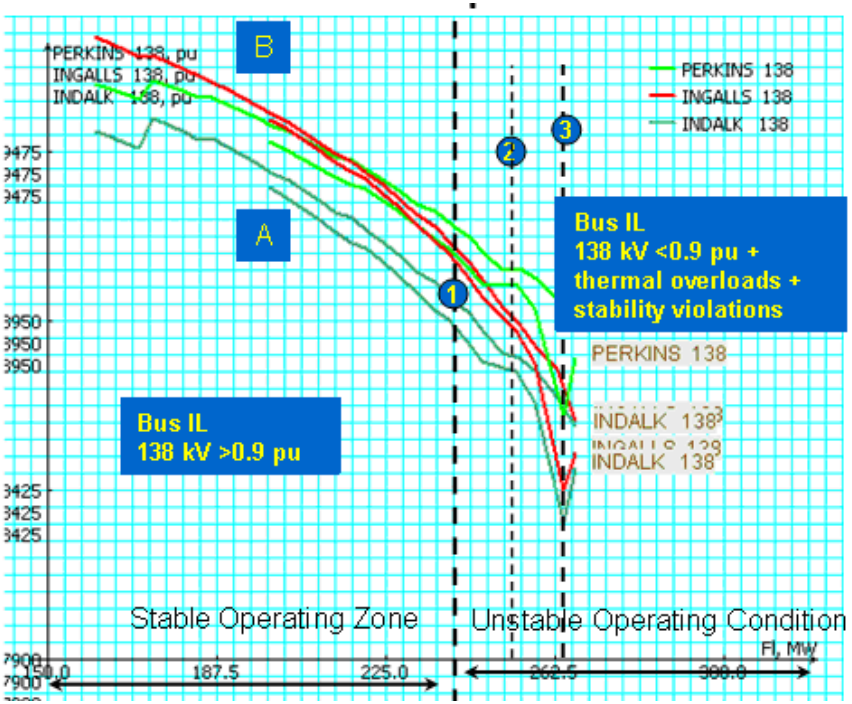
# PV- Curve Analysis

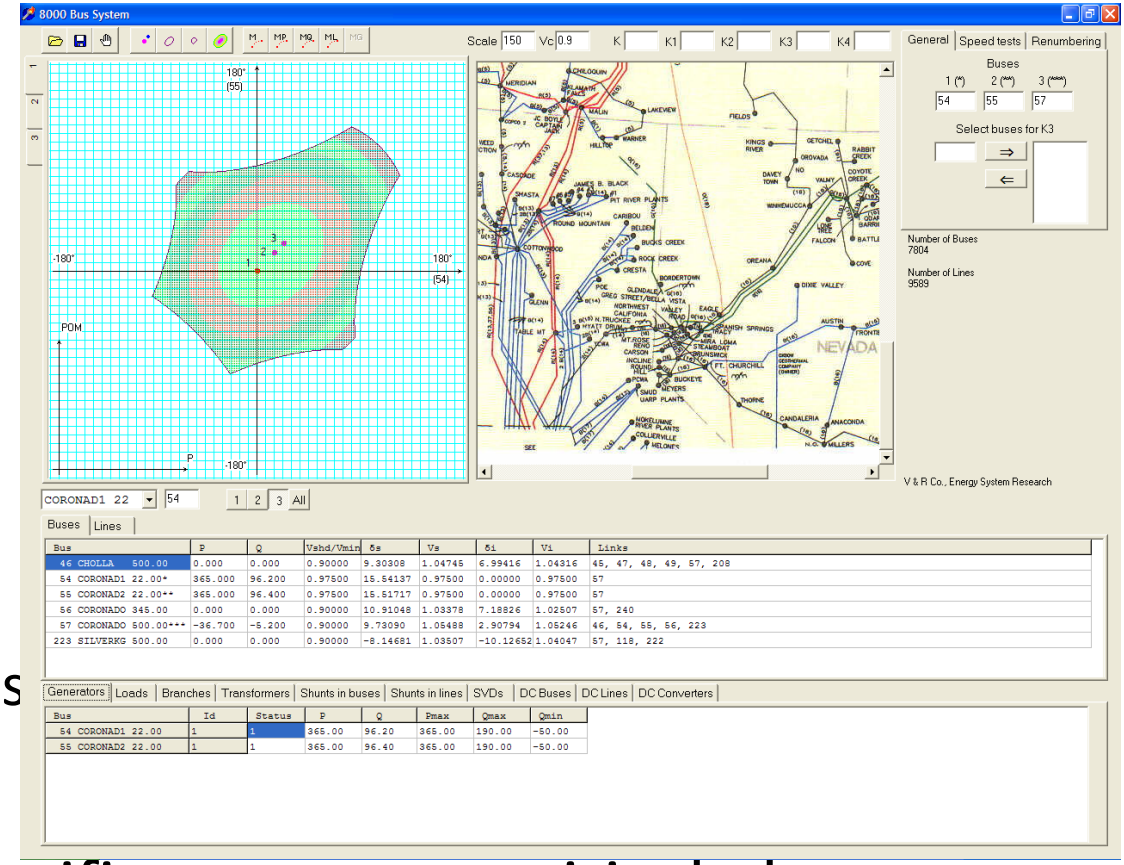
- Used for interfaces in the power system that are sensitive to voltage collapse
  - Then, operating limits are established
- Quickly re-evaluate the limits as system conditions change



# 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

# Conclusion

- You can either do it

  or

- Do it **RIGHT** with ROSE