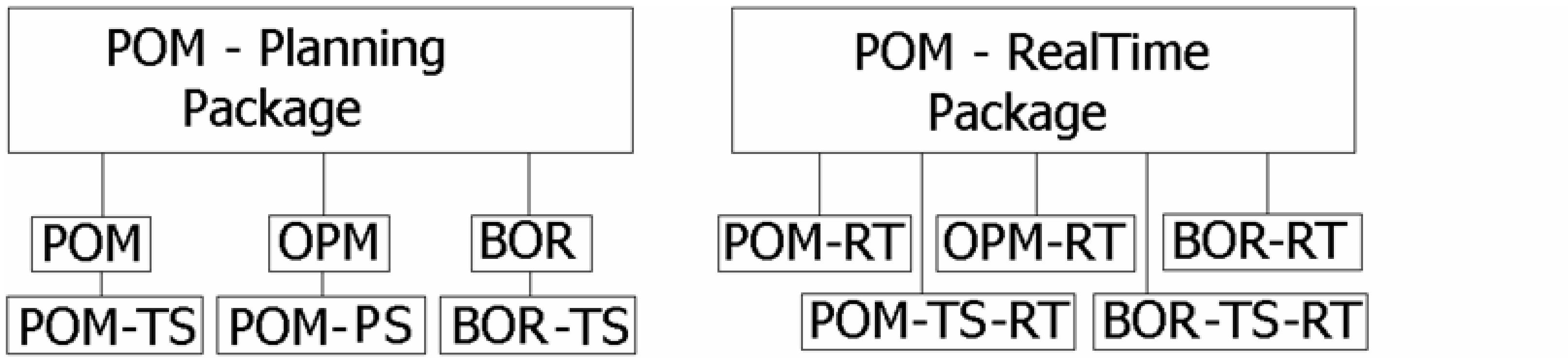
# V&R Energy

# Transmission System Optimization SOFTWARE OVERVIEW

October 13, 2005

# Physical and Operational Margins (POM) Suite of Software




POM - Physical and Operational Margins

OPM - OPtimal Mitigation Measures

BOR - Boundary of Operating Region

POM-TS - POM-Transient Stability

POM-PS - POM-Project Selection

BOR-TS - BOR-Transient Stability

ROSE - Region of Security Estimation (using phasor data)

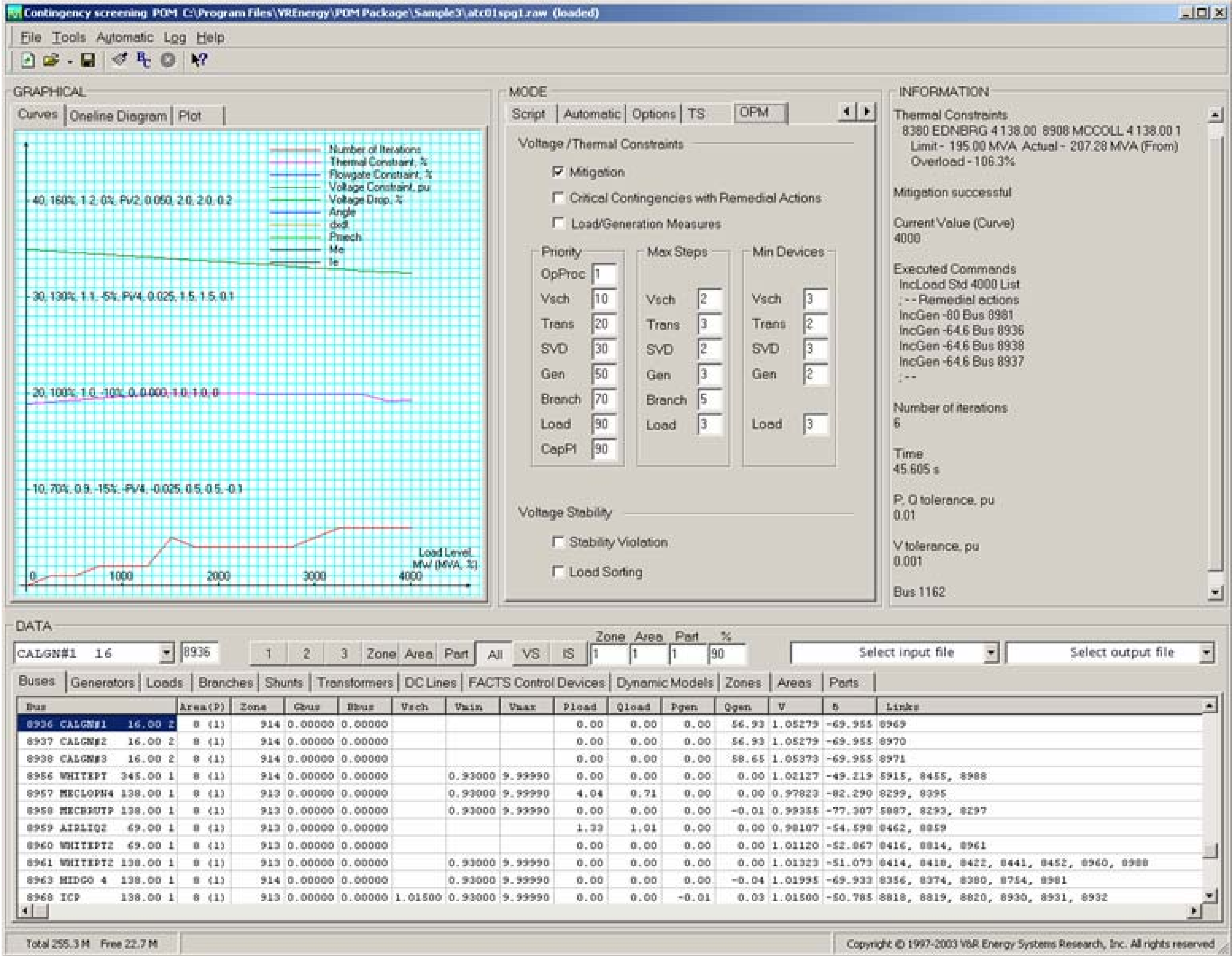
# User-Group Members
## (Listed in Alphabetical Order)

- AEP
- ATC
- BPA
- ConEd
- Entergy
- EPRI Solution
- Idaho Power
- ISO New England
- KCPL
- KEPCO
- KeySpan/LIPA
- Midwest ISO
- ONS
- NYPA
- Tri-State G&T
- TVA

# POM Software Configuration

- POM software is owned and developed by V&R Energy Systems Research, Inc.
- The most powerful and sophisticated application suite on the market providing fastest solution of load flows, transient analysis, and real time analysis. Suite can graphically display boundaries of operating reliability, determine optimum mitigation measures, and optimal rank of transmission expansion projects.
- Can be used for planning and operations environments:
  - POM- Planning Package
    - Used for Long Range and Operational Planning
  - POM-RealTime Package
- All programs in the package are fully integrated and utilize the same interface that is Microsoft Windows-based
- Any software configuration is available, based on a customer request

# POM Software



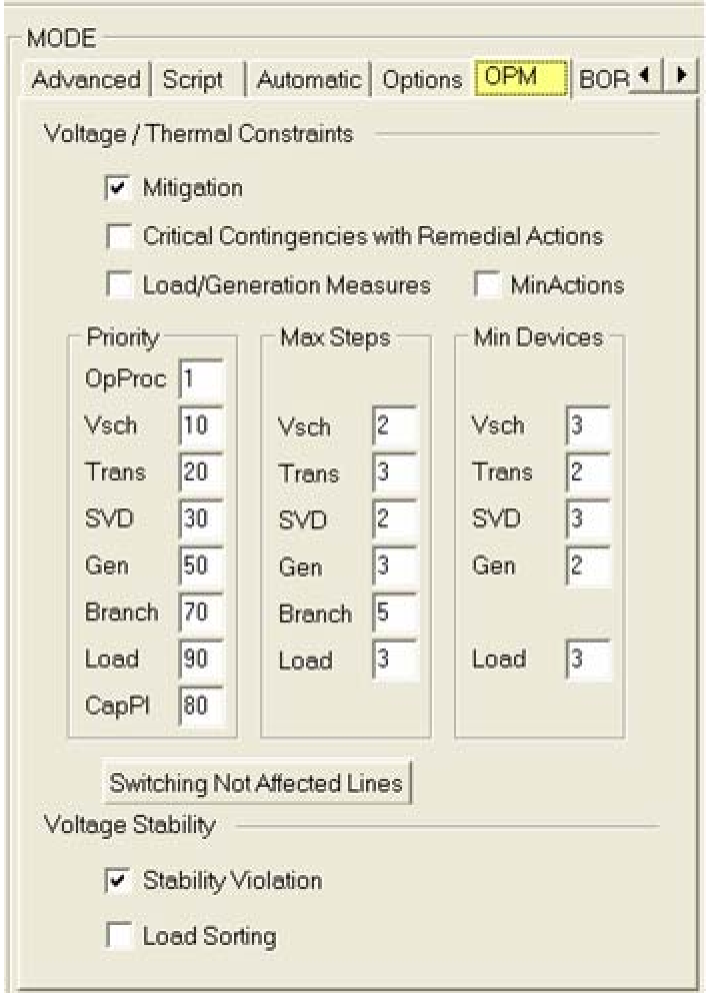
# POM Advantages

AC analysis load flow that allows the user to simultaneously monitor voltage stability, voltage, thermal and flow gate constraints

- Extremely fast – solves a 45,000 bus case in ~ 0.6 sec
- Provides reliable and robust solution engine (can converge when other planning and advanced application software or engines reach an unanalyzed state and can't analyze the system).
- Very flexible user-friendly and intuituve interface that incorporates the latest technological advances
- Extensive visual representation of the power system behavior, that includes interactive one-line diagrams and maps. Boundary of Operating Region is displayed in 2-D and 3-D
- Supports operations in automatic and interactive modes, as well as the use of scripting language to quickly tailor the software to customer specific applications.
- Easy-to-use, flexible, intuitive script; no compiling needed; offers intelli-sense –no need to remember the format and syntax of the scripting functions
- All additional application modules are fully integrated into the main program

# Capabilities of OPtimal Mitigation Measures- OPM

- Fast, powerful and efficient remedial actions or transmission expansion planning program
- Fully integrated into POM
  - Works in all POM modes: Basic, Advanced and Automatic
- Relieves thermal, voltage and voltage stability violations identified by POM
  - Determines the minimum actions needed to alleviate violations, based on user-specified priorities
  - Determines the causes of stability violations
  - Increases voltage stability margins
  - Increases transfer capability



# Possible Mitigation Measures Used in OPM

- Applies a minimum number of mitigation measures based on a user-defined priority schedule which may include:
  - MW Dispatch
  - MVar Dispatch
  - Capacitor and Reactor Switching
  - Transformer Tap Change
  - Line Switching (In and Out)
  - Optimal Capacitor, Reactor, FACTS Placement and size
  - Phase Shifter settings
  - Load Curtailment
  - Defined Operating Procedures
  - Switching Not Affected Lines

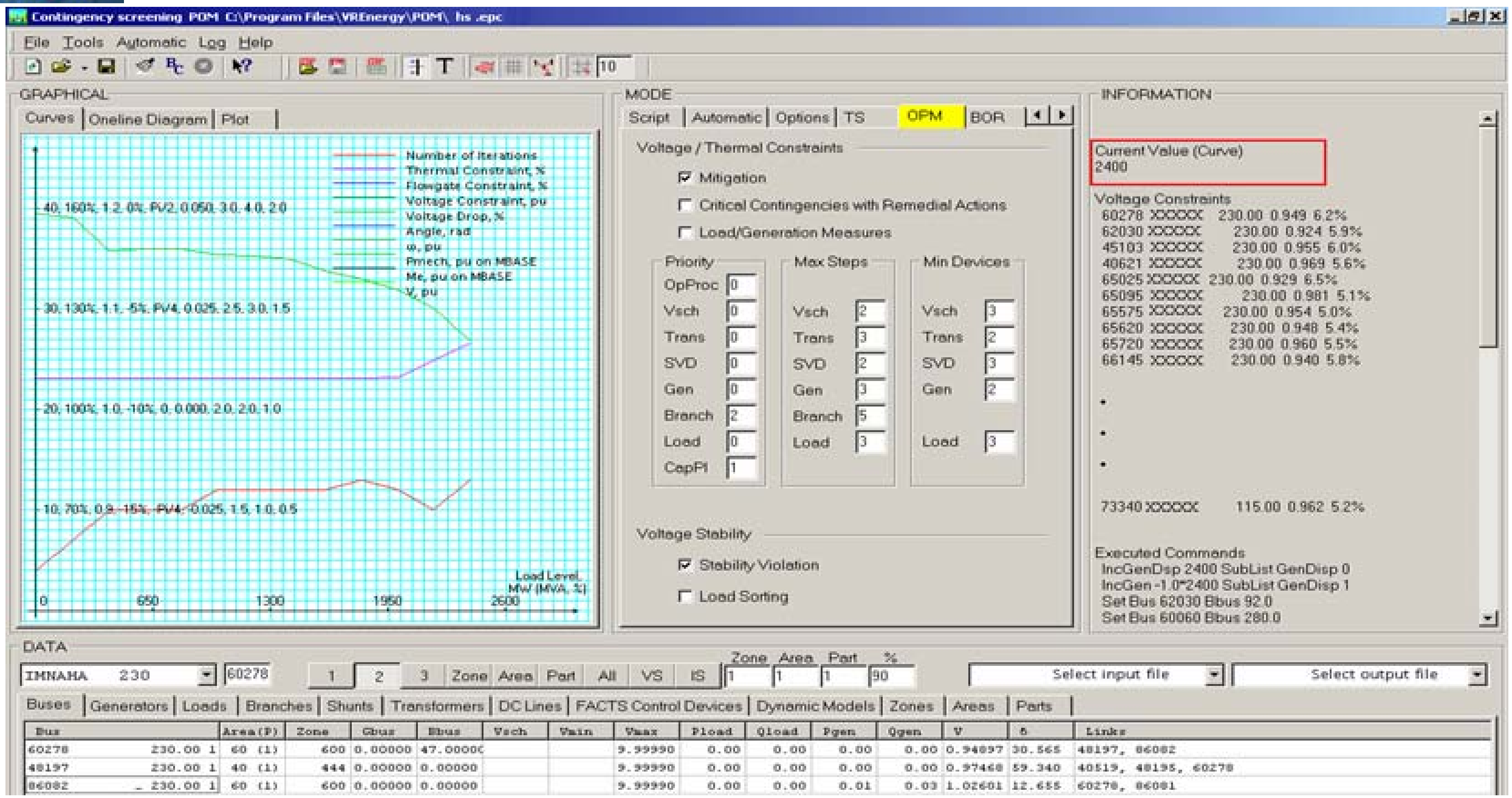
# Switching Not Affected Lines

- Uniquely allows a user to alleviate the thermal overloads by switching not affected (i.e., non-overloaded) branches
  - Automatically selects the lines that must be switched, in order to effectively alleviate the overloads
  - Works very fast in quasi real-time
  - The sum of all overloads, which is identified after a measure is applied, is used as an index where 0% corresponds to those overloads which are completely alleviated as a result of the suggested measure

# OPM Features (using both optimization technique and sensitivity analysis)

- Determines only the load and generation measures and actions based on changes in network/power flow parameters after a contingency (for example, power flow direction, bus mismatches, etc.).
- Determines the measure and action for each contingency along with a margin within which the mitigation measures are effective (for each contingency). Applies the measure and actions after a contingency is introduced whereby post-contingency violations are alleviated and the contingency is no longer critical, applies the contingency at a next load/transfer step and determines the actions needed to alleviate the resulting violations, and finally repeats the above steps until remedial actions become ineffective.

# Using OPM to Increase Transfer Capability




- **OPM increases the power transfer from 1200 MW to 2400 MW!**

# The Concept of Boundary of Operating Region (BOR)

- Boundary of Operating Region (BOR) is a powerful tool used to identify and illustrate the region within which the system operation is secure  automatically generating nomograms for planning and real-time environments
- BOR is used to determine:
  - Effect of changing one parameter on another, for example, simultaneous power transfer limits
  - Effects of outages on secure region of operation
  - Effects of mitigation measures and actions on secure region of operation
  - When used with OPM, determines the most effective mitigation measures as OPM increases the size of the operating region

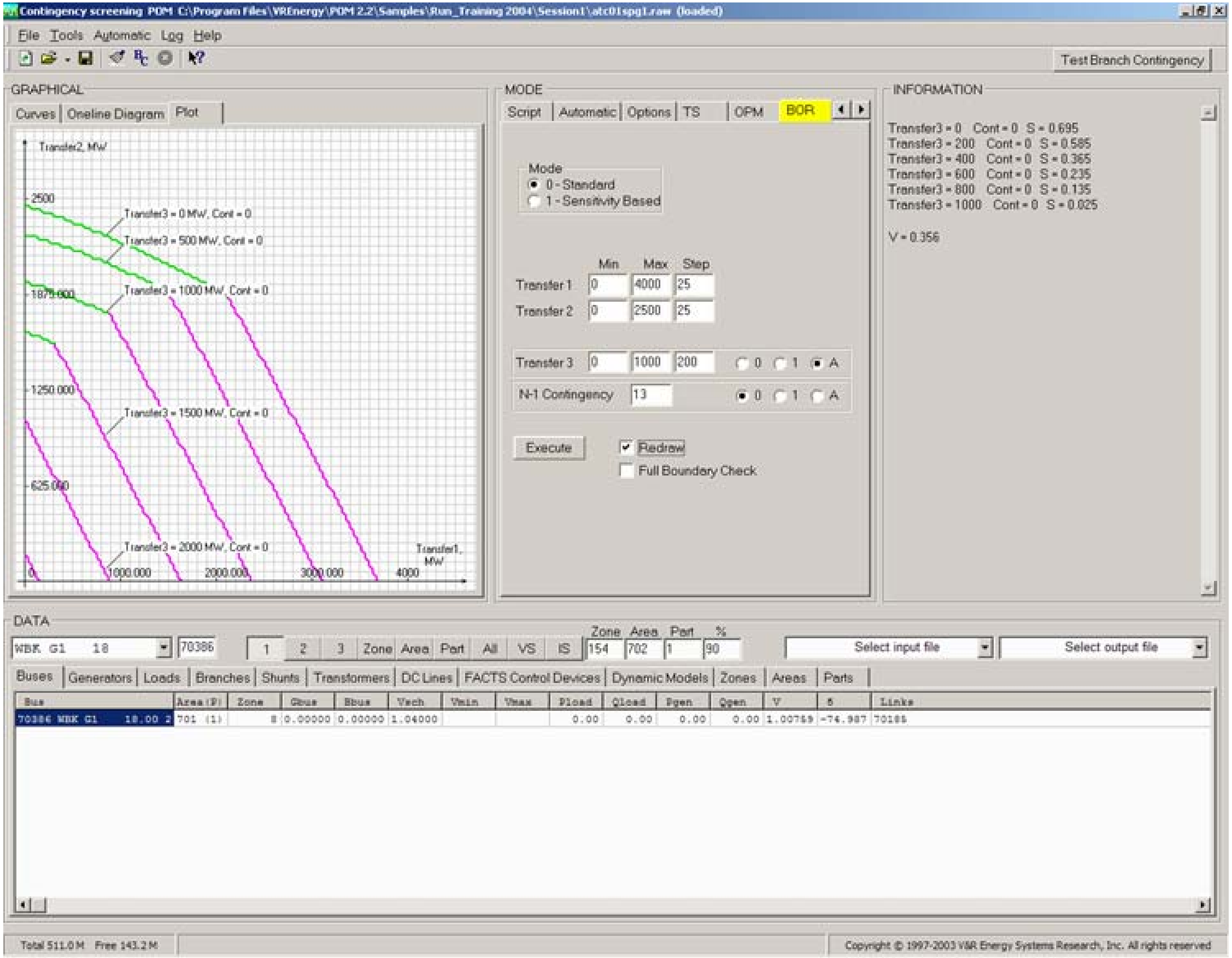
# BOR Features

- Determines various power transfer scenarios to achieve the maximum transfer capability:
  - Maximizes the existing transfer(s) without any topology change and/or additional resources
  - Maximizes the transfers based on optimal redistribution of source/sink resources while honoring all specified limits
- Determines power transfer scenarios to achieve the minimum cost:
  - Minimizes the cost of existing transfer(s) without any topology change and/or additional resources
  - Minimizes the cost of the transfers based on optimal redistribution of source/sink resources while honoring all specified limits

# BOR Graphical Output

- Graphical output represents the Boundary of the Operating Region
  - Each point on the boundary corresponds to at least one of the constraints being violated
  - Each color corresponds to a limiting constraint
    - Pink - Thermal violation
    - Green - Voltage range violation
    - Dark green - Pre- to post-contingency voltage drop violation
    - Teal - Flowgate violation
    - Red - Voltage stability violation
    - Black (thin) - User-specified transfer limit is reached but no violations are identified
    - Black (thick) - All available generation (load) in source/sink subsystems has been used

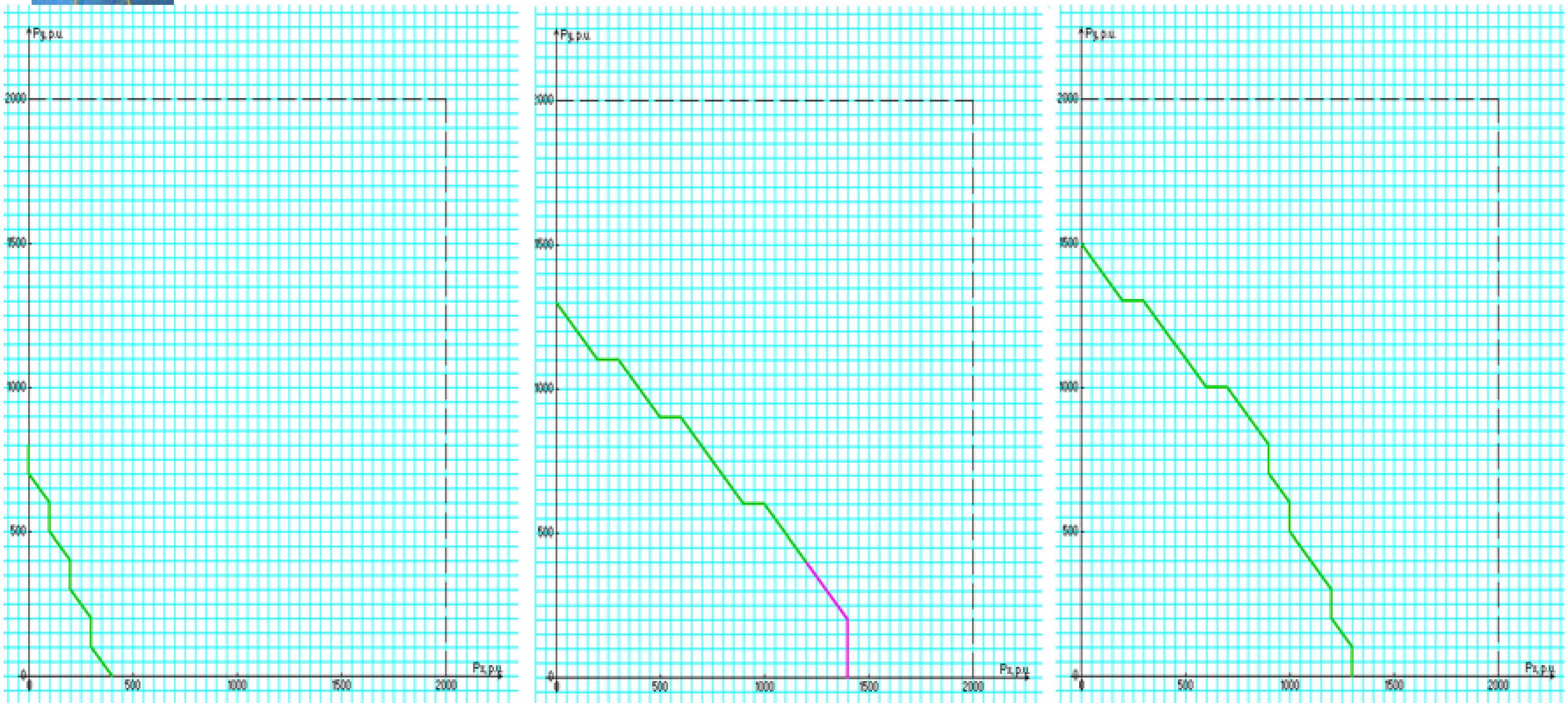
# BOR Interface



# BOR Advantages

- BOR is an add-on module fully integrated into POM interface
- Monitored limits incorporated in BOR are:
  - Steady-state stability limit
  - Thermal limit
  - Voltage range/drop limit
  - Flowgate limit
- Finds AC limits for transfer scenarios based on voltage stability, voltage constraints, and thermal constraints
  - MUST’s AC Transfer Limit Analysis is based only on voltage stability and thermal constraints
- Boundary of Operating Region can be graphically exhibited as a projection onto different coordinate planes, such as:
  - Power transfers
  - Load and generation
  - Interface and/or tie-line flows
  - Phase-shifter flows

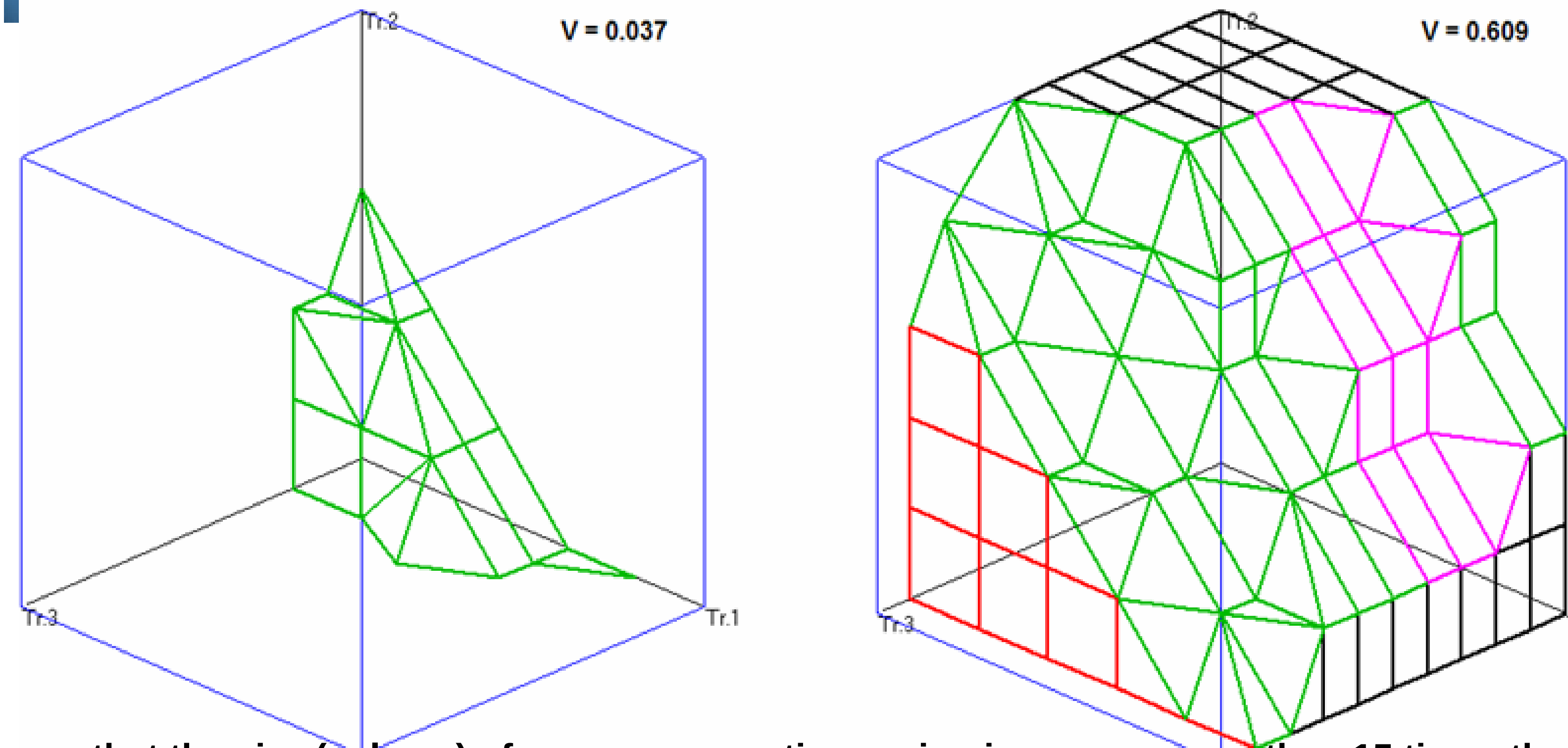
# Example of Analyzing the Impact of Installing Different Types of Sources of Reactive Power Using BOR with OPM and GUI




*(a)* *(b)* *(c)*

**The region is shown on the plane of two simultaneous power transfers. Green color on the boundary corresponds to voltage violations, pink – to thermal overloads. Plot (a) corresponds to the operating region prior to installing the VAR sources. Plots (b) and (c) show the increase of the secure operating region after different types of reactive sources are installed.**

# Effect of Placing Reactive Sources on the Secure Operating Region



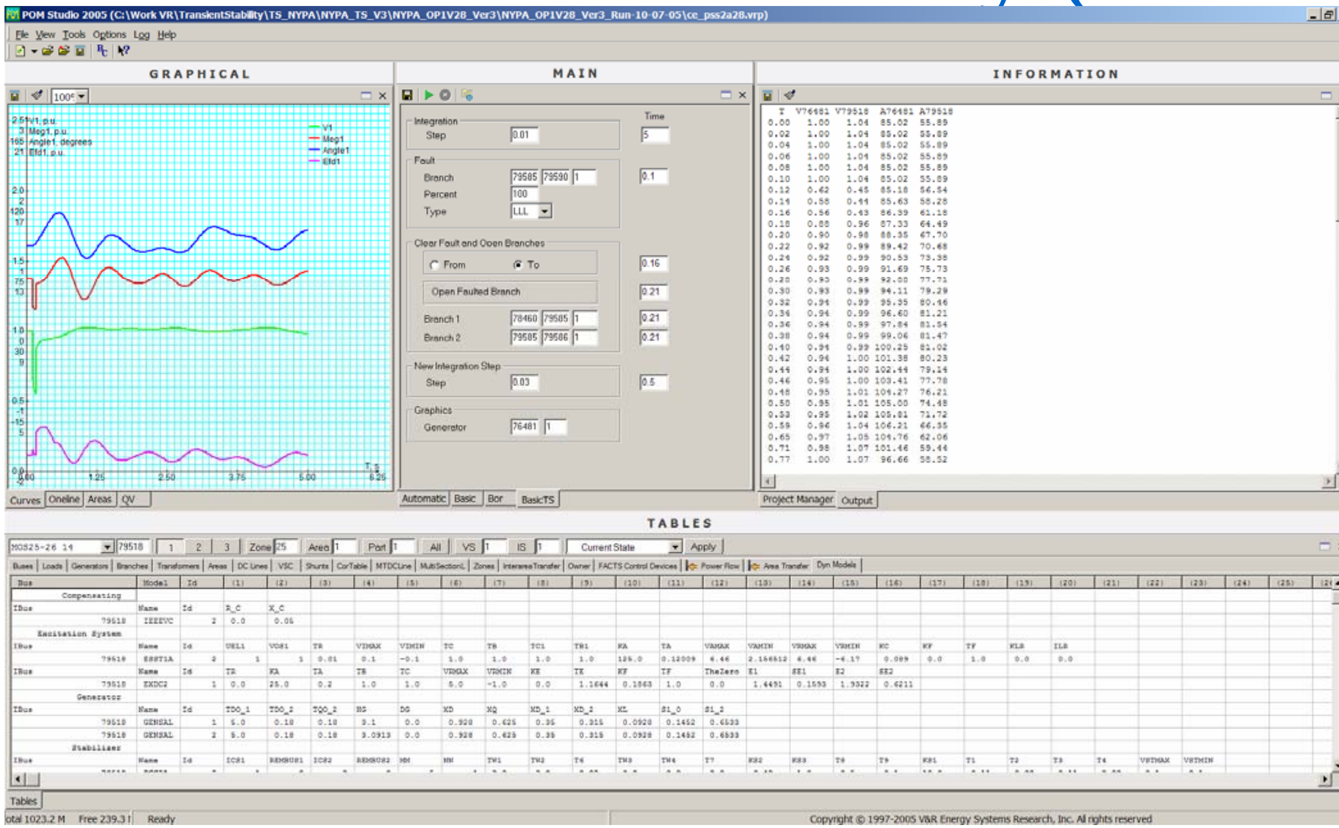

**This shows that the size (volume) of a secure operating region increases more than 15 times the original value (from 0.037 to 0.609) after the reactive sources are optimally added. The region is shown in the space of three simultaneous power transfers along major transmission paths. Colors on the boundaries are:**

**Green is Steady-state voltage constraint, Red is Voltage stability limit, Pink is Thermal overload.**

**Black portion of the boundary (right plot) corresponds to the user-specified transfer limit being reached with no violations identified.**

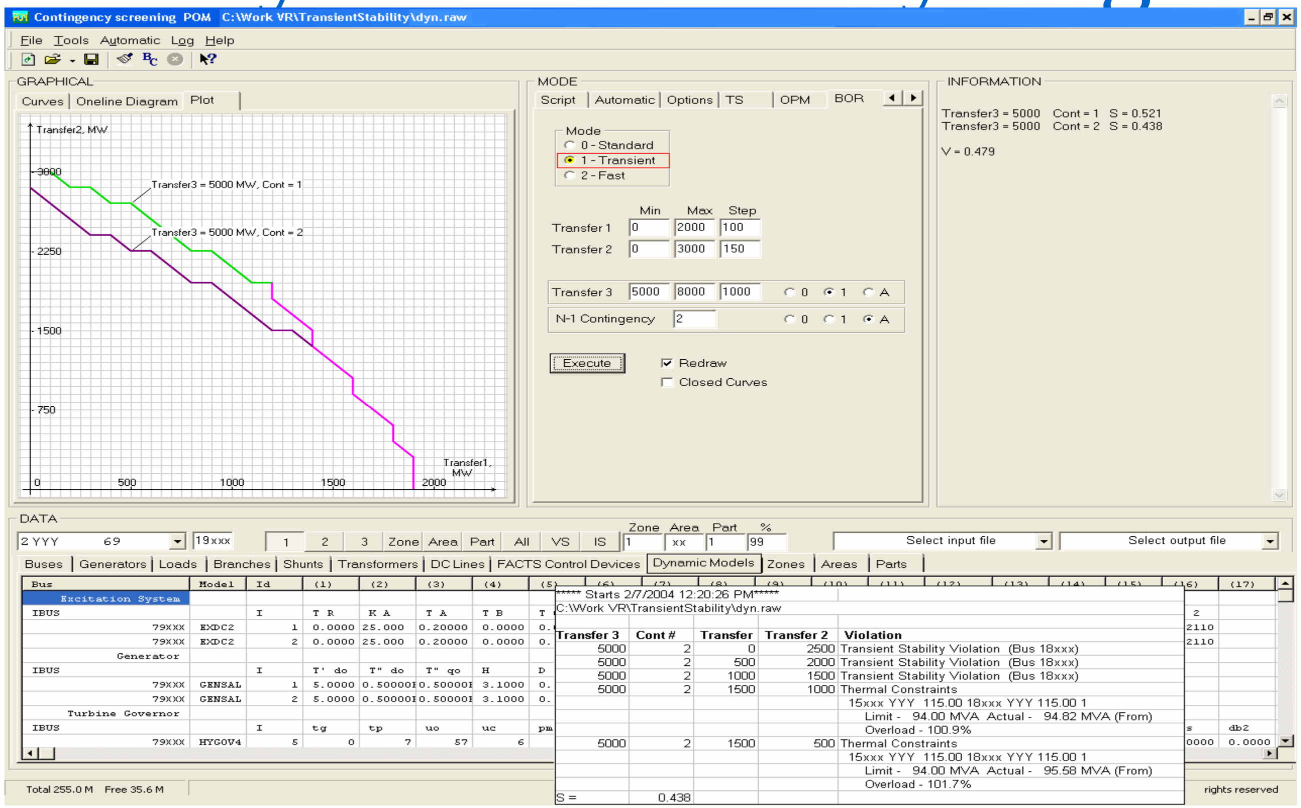
**The proposed approach will allow RTOs, ISO, and utilities to significantly increase both the effectiveness and reliability of operating the interconnected system under various transfer and contingency conditions.**

# POM-Transient Stability (POM-TS)




- Extremely easy to use
  - All options are available from the interface; no compiling required
  - Directly reads dynamic data in PSS/E and PSLF formats; no conversions required
- Very fast: 10 times faster than PSS/E as benchmarked with NYPA
- Offers great flexibility in graphical and tabular output

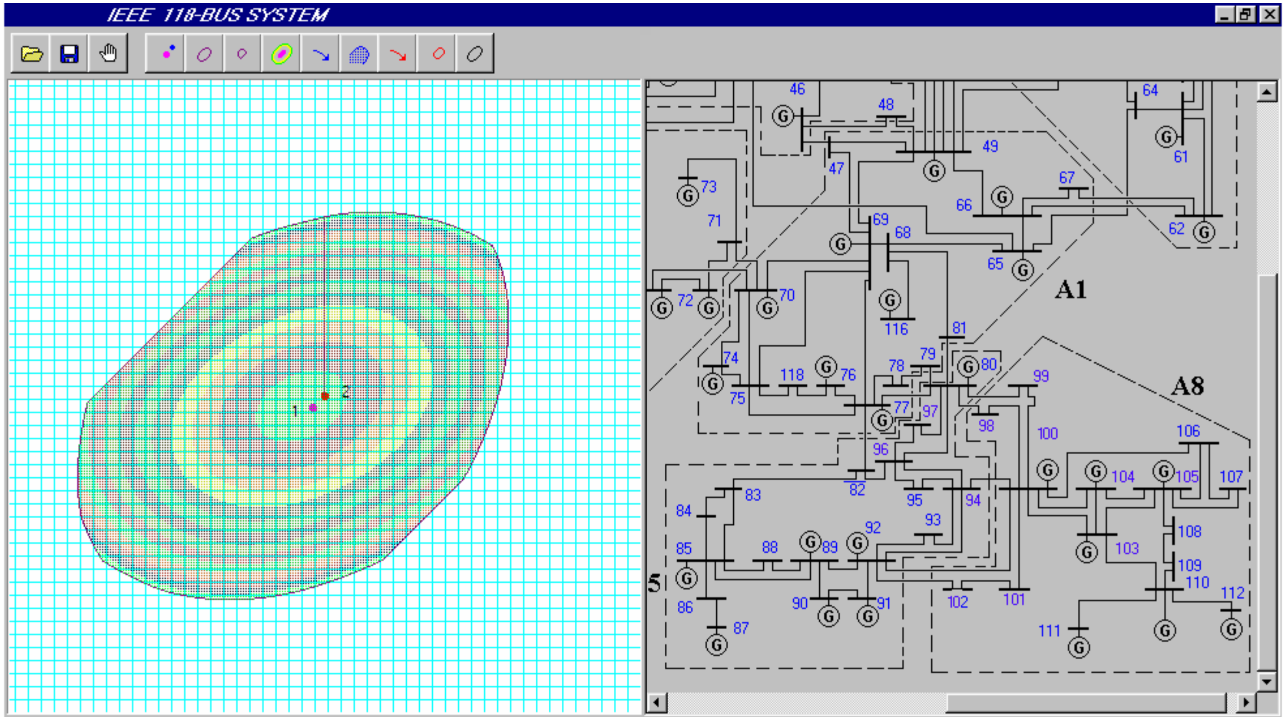
# BOR-Transient Stability (BOR-TS): Dynamic Security Region




- Monitoring of transient stability violations is added to BOR
- Monitored limits incorporated in BOR-TS are:
  - Transient stability, Steady-state stability, Thermal, Voltage range/drop, Flowgate

# Region of Stability Existence (ROSE ) Approach

- **ROSE approach below is based on the analytical expression for the region of existence of power flow solution**
- **The approach will provide the operator with both fast and accurate solutions in order to predict system instability and prevent wide-spread blackouts while utilizing PMU phasor data**




Load Flow Data

| Bus | P | Q | U/Uc | BB | GG | H |
|---|---|---|---|---|---|---|
| 96 | 4.3739 | -0.1374 | 0.5000 | 60.5038 | -16.8940 | |
| 97 | 0.1539 | -0.1011 | 0.5000 | 21.1697 | -4.1477 | |
| 98 | 0.3396 | -0.0727 | 0.5000 | 14.1170 | -3.1269 | |
| 99 | 0.4193 | | 1.0100 | 16.3168 | -3.6163 | 4.0000 |
| 100 | 2.1399 | | 1.0170 | 69.5955 | -18.4057 | 4.0000 |
| 101 | 0.2160 | -0.1416 | 0.5000 | 16.0463 | -3.5301 | |

Line Parameters

| From | To | B | G |
|---|---|---|---|
| 96 | 97 | -10.8835 | 2.1275 |
| 98 | 100 | -5.3247 | 1.1809 |
| 99 | 100 | -11.7254 | 2.5960 |
| 100 | 101 | -7.5597 | 1.6593 |
| 100 | 103 | -17.4288 | 5.3116 |
| 100 | 104 | -4.6735 | 1.0332 |

Coordinates

| Bus | Xeq | Ueq | Xi | Ui | Xs |
|---|---|---|---|---|---|
| 96*** | -0.33 | 0.95 | -0.16 | 0.95 | |
| 97 | -0.23 | 0.98 | -0.09 | 0.98 | |
| 98 | -0.19 | 1.02 | -0.02 | 1.02 | |
| 99 | -0.24 | 1.01 | 0.00 | 1.01 | -0.24 |
| 100 | -0.25 | 1.02 | 0.00 | 1.02 | -0.25 |
| 101 | -0.23 | 0.99 | -0.01 | 0.99 | |

Y&R Co., Energy System Research

# ROSE Project Task Performance

1. **Determine the relationship between the region of stability existence and the maximum loadability in the loads of interest in a bulk power system. Demonstrate that transmission congestion can be minimized by at least 20% by using ROSE.**

2. **Determine the relationship between the region of stability existence and the maximum transfer capability for the specific interfaces in a bulk power system. Demonstrate that the maximum transfer capability can be increased by at least 10% by using ROSE thus reducing the cost of delivered power to the customer by allowing increased access to lower cost power.**

3. **Compute the region for an arbitrary number of phasor measurements using data in real time. Demonstrate that ROSE can be computed for an arbitrary number of available phasor measurements.**

# ROSE Shown for a WECC System Case

- **Point 1 corresponds to the base case condition (i.e., point (0, 0))**
- **Points 2 and 3 correspond to different values of the simulated transfer**
  - **Voltage, thermal and flow gate constraints may be simultaneously monitored in ROSE in addition to voltage**