



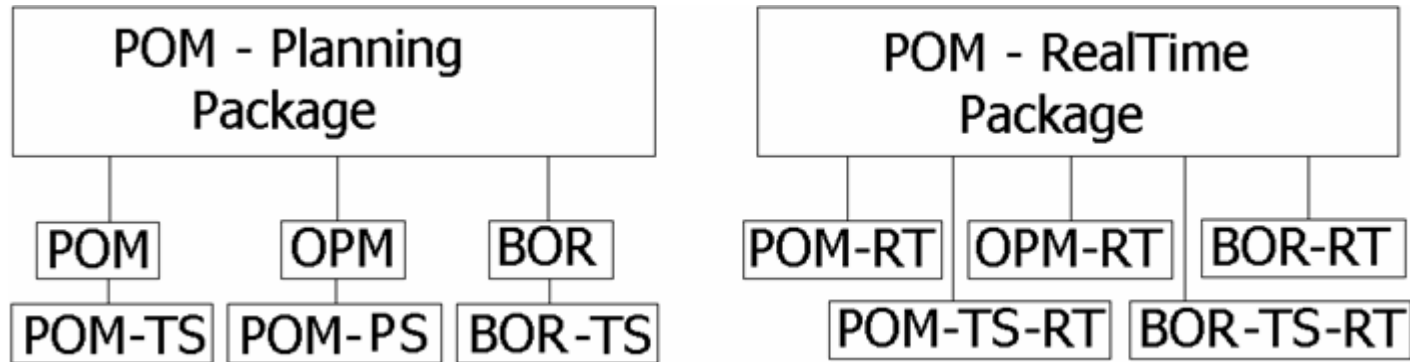
V&R Energy

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

Contingency screening POM C:\Program Files\VREnergy\POM Package\Sample3\atc01spg1.raw (loaded)

File Tools Automatic Log Help

GRAPHICAL: Curves | Online Diagram | Plot

MODE: Script | Automatic | Options | TS | OPM

Voltage / Thermal Constraints

Mitigation

Critical Contingencies with Remedial Actions

Load/Generation Measures

Priority: OpProc 1, Vsch 10, Trans 20, SVD 30, Gen 50, Branch 70, Load 90, CapFl 90

Max Steps: Vsch 2, Trans 3, SVD 2, Gen 3, Branch 5, Load 3

Min Devices: Vsch 3, Trans 2, SVD 3, Gen 2, Load 3

Voltage Stability: Stability Violation, Load Sorting

INFORMATION: Thermal Constraints: 8380 EDNBRG 4 138.00 8908 MCCOLL 4 138.00 1 Limit - 195.00 MVA Actual - 207.28 MVA (From) Overloaded - 106.3%

Mitigation successful

Current Value (Curve) 4000

Executed Commands: IncLoad Std 4000 List, Remedial actions: IncGen -80 Bus 8981, IncGen -64.6 Bus 8936, IncGen -64.6 Bus 8938, IncGen -64.6 Bus 8937

Number of iterations 6

Time 45.605 s

P. Q tolerance. pu 0.01

V tolerance. pu 0.001

Bus 1162

DATA: Zone Area Part %

CALGN#1 16 8936 1 2 3 Zone Area Part All VS IS 1 1 1 90

Select input file Select output file

Bus	Generators	Loads	Branches	Shunts	Transformers	DC Lines	FACTS Control Devices	Dynamic Models	Zones	Areas	Parts	Links			
Bus	Area(P)	Zone	Cbus	Hbus	Vsch	Vmin	Vmax	Pload	Qload	Pgen	Qgen	V	S	Links	
8926 CALGN#1	16.00	2	8 (1)	914	0.00000	0.00000		0.00	0.00	0.00	0.00	56.93	1.05279	-69.955 8969	
8937 CALGN#2	16.00	2	8 (1)	914	0.00000	0.00000		0.00	0.00	0.00	0.00	56.93	1.05279	-69.955 8970	
8938 CALGN#3	16.00	2	8 (1)	914	0.00000	0.00000		0.00	0.00	0.00	0.00	58.65	1.05373	-69.955 8971	
8956 WHITEPT	345.00	1	8 (1)	914	0.00000	0.00000	0.93000	9.99990	0.00	0.00	0.00	0.00	1.02127	-49.219 8915, 8455, 8988	
8957 MECLOPM4	138.00	1	8 (1)	913	0.00000	0.00000	0.93000	9.99990	4.04	0.71	0.00	0.00	0.97823	-82.290 8239, 8395	
8958 MECSRUP	138.00	1	8 (1)	913	0.00000	0.00000	0.93000	9.99990	0.00	0.00	0.00	-0.01	0.99355	-77.307 8087, 8293, 8297	
8959 AIPLIQ2	69.00	1	8 (1)	913	0.00000	0.00000			1.33	1.01	0.00	0.00	0.98107	-54.598 8462, 8859	
8960 WHITEPT2	69.00	1	8 (1)	913	0.00000	0.00000			0.00	0.00	0.00	0.00	1.01120	-52.867 8416, 8814, 8961	
8961 WHITEPT2	138.00	1	8 (1)	913	0.00000	0.00000	0.93000	9.99990	0.00	0.00	0.00	0.00	1.01323	-51.073 8414, 8418, 8422, 8441, 8452, 8960, 8988	
8963 MIDCO 4	138.00	1	8 (1)	914	0.00000	0.00000	0.93000	9.99990	0.00	0.00	0.00	-0.04	1.01995	-69.933 8356, 8374, 8380, 8754, 8981	
8968 ICP	138.00	1	8 (1)	913	0.00000	0.00000	1.01500	0.93000	9.99990	0.00	0.00	-0.01	0.03	1.01500	-50.785 8818, 8819, 8820, 8930, 8931, 8932

Total 255.3 M Free 22.7 M

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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 intuitive 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

MODE
Advanced | Script | Automatic | Options | OPM | BOR ◀ ▶

Voltage / Thermal Constraints

Mitigation
 Critical Contingencies with Remedial Actions
 Load/Generation Measures MinActions

Priority	Max Steps	Min Devices
OpProc 1	Vsch 2	Vsch 3
Vsch 10	Trans 3	Trans 2
Trans 20	SVD 2	SVD 3
SVD 30	Gen 3	Gen 2
Gen 50	Branch 5	
Branch 70	Load 3	Load 3
Load 90		
CapPl 80		

Switching Not Affected Lines

Voltage Stability

Stability Violation
 Load Sorting



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

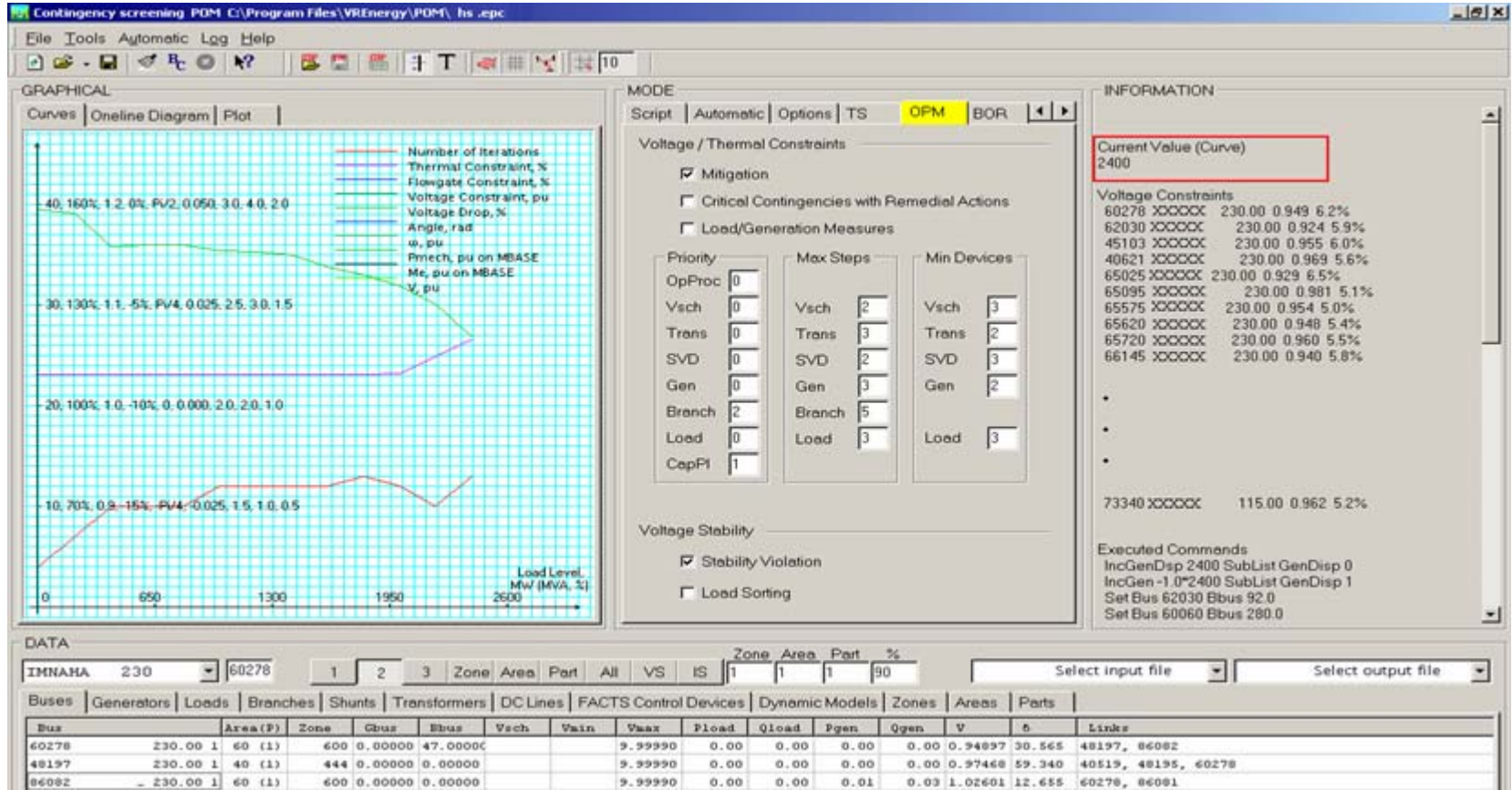


OPM Features (using both optimization technique and sensitivity analysis)

- 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

Contingency screening (POM C:\Program Files\VEREnergy\POM 2.2\Samples\Run_Training 2004\Session1\atc01spg1.raw (loaded))

File Tools Automatic Log Help

GRAPHICAL Curves Online Diagram Plot

MODE Script Automatic Options TS OPM **BOR**

Mode
 0 - Standard
 1 - Sensitivity Based

	Min	Max	Step
Transfer 1	0	4000	25
Transfer 2	0	2500	25
Transfer 3	0	1000	200

N-1 Contingency 13 0 1 A

Execute Redraw Full Boundary Check

INFORMATION

Transfer3 = 0 Cont = 0 S = 0.695
 Transfer3 = 200 Cont = 0 S = 0.585
 Transfer3 = 400 Cont = 0 S = 0.365
 Transfer3 = 600 Cont = 0 S = 0.235
 Transfer3 = 800 Cont = 0 S = 0.135
 Transfer3 = 1000 Cont = 0 S = 0.025

V = 0.356

DATA

WBK G1 18 70386 1 2 3 Zone Area Part % 154 702 1 90

Select input file Select output file

Bus	Area (F)	Zone	Cbus	Bbus	Vech	Vmin	Vmax	Pload	Qload	Pgen	Qgen	V	θ	Links
70386 WBK G1 18.00 2	701 (1)	8	0.00000	0.00000	1.04000			0.00	0.00	0.00	0.00	1.00769	-74.987	70185

Total 511.0 M Free 143.2 M

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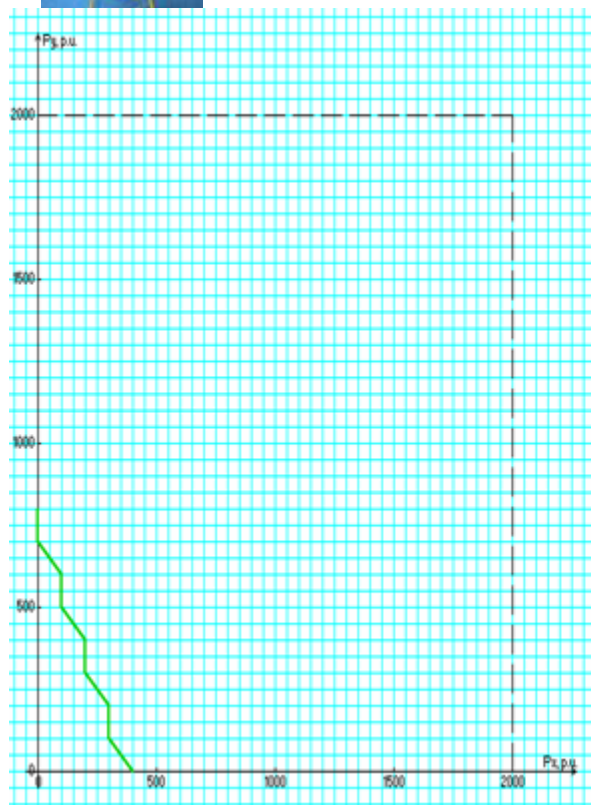


BOR Advantages

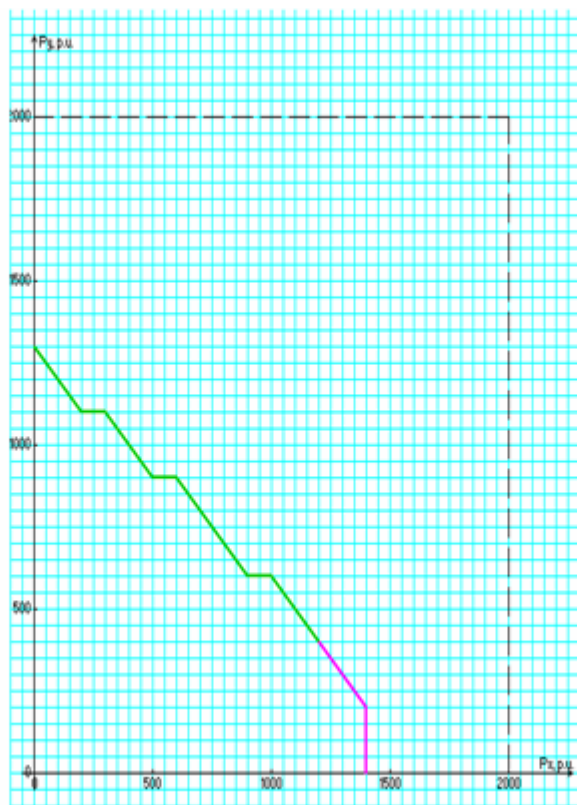
- BOR is an add-on module fully integrated into POM interface
- Monitored limits incorporated in BOR are:
 - Steady-state stability limit
 - Thermal limit
 - Voltage range/drop limit
 - Flowgate limit
- Finds AC limits for transfer scenarios based on voltage stability, voltage constraints, and thermal 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



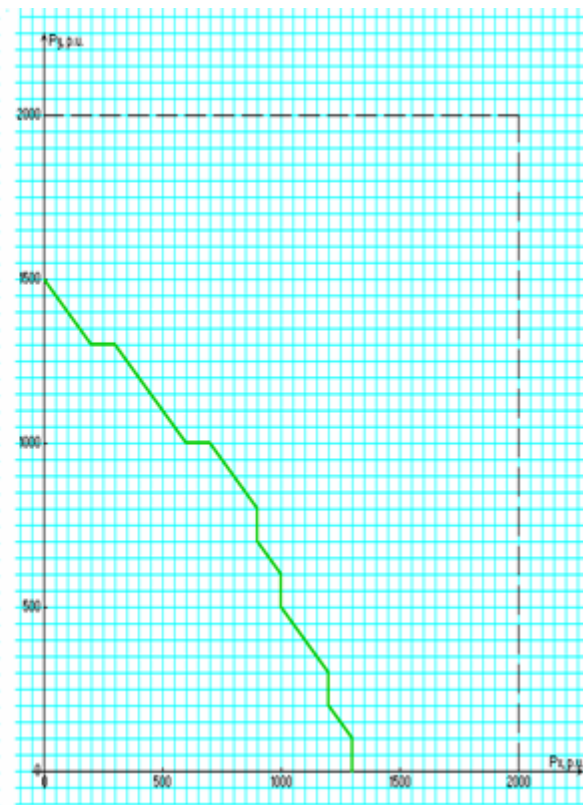
Example of Analyzing the Impact of Installing Different Types of Sources of Reactive Power Using BOR with OPM and GUI



(a)



(b)

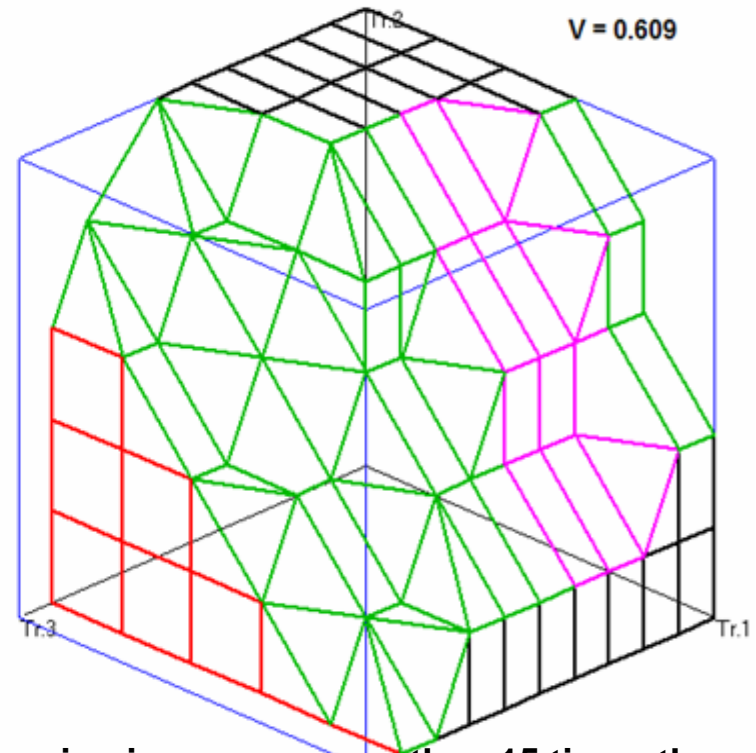
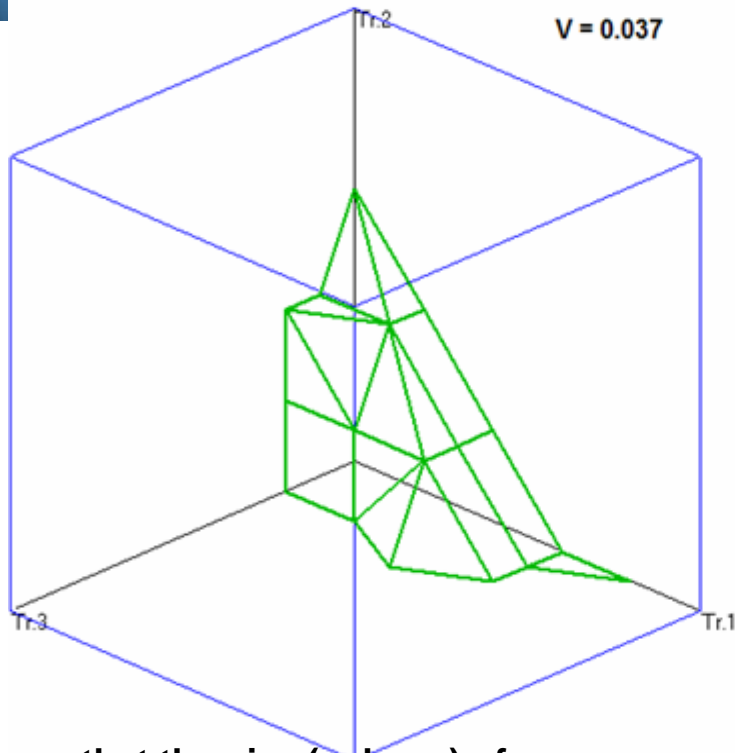


(c)

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:

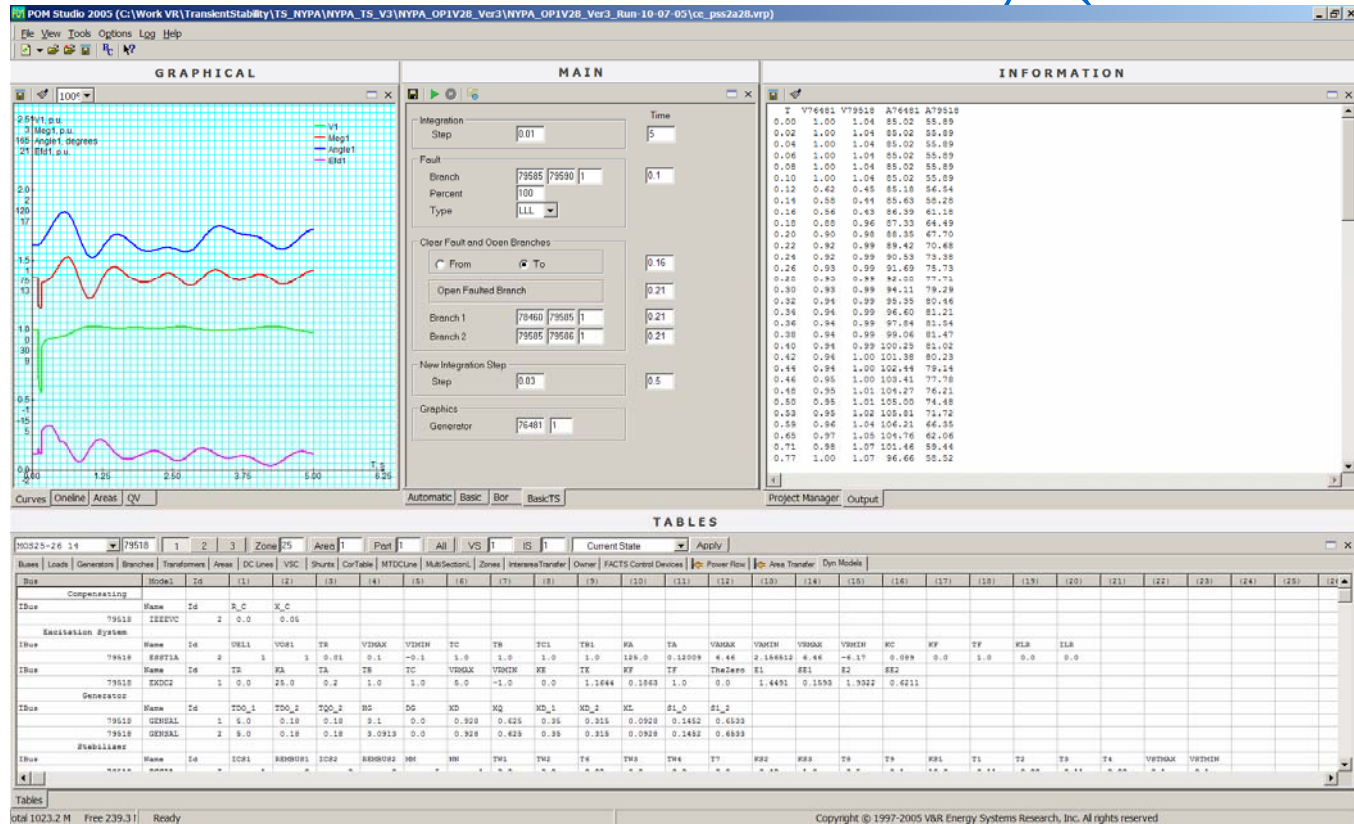
Green is Steady-state voltage constraint, Red is Voltage stability limit, Pink is Thermal overload.

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.



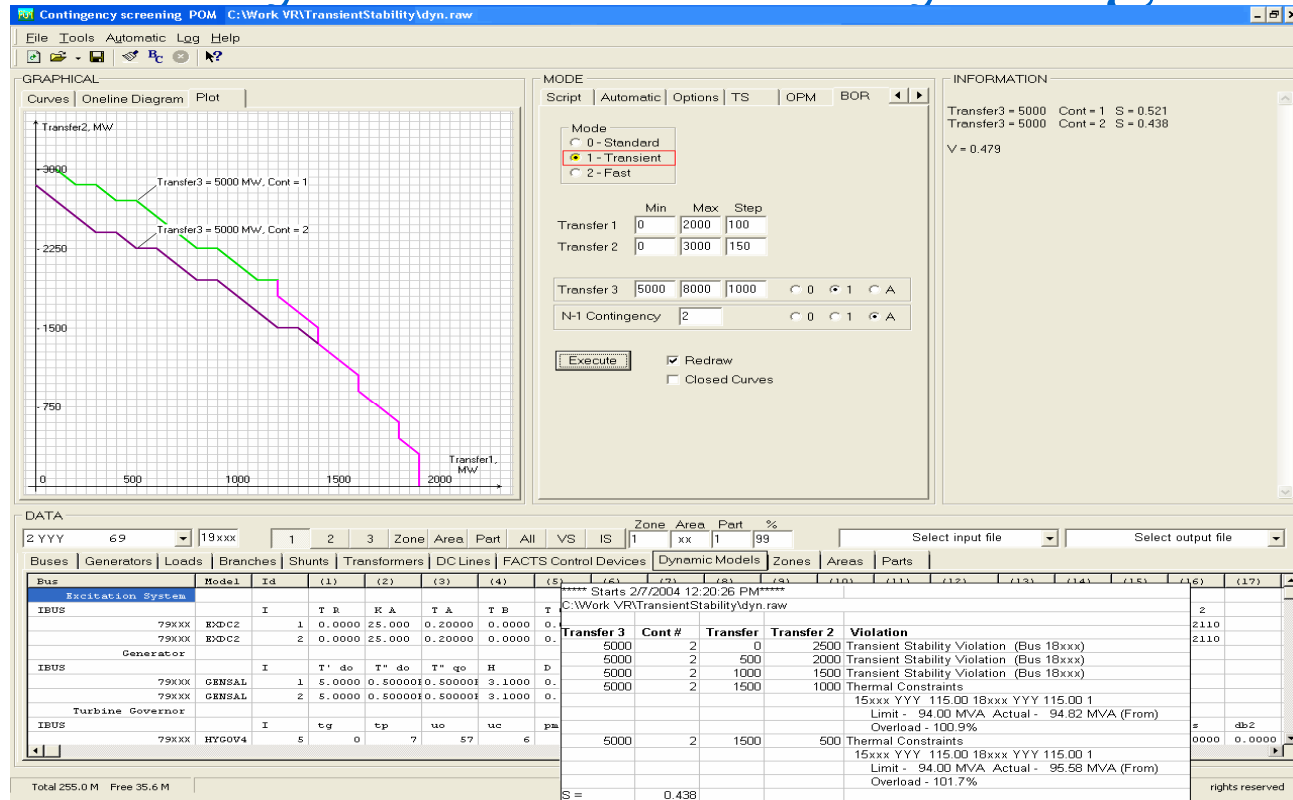
POM-Transient Stability (POM-TS)



- 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

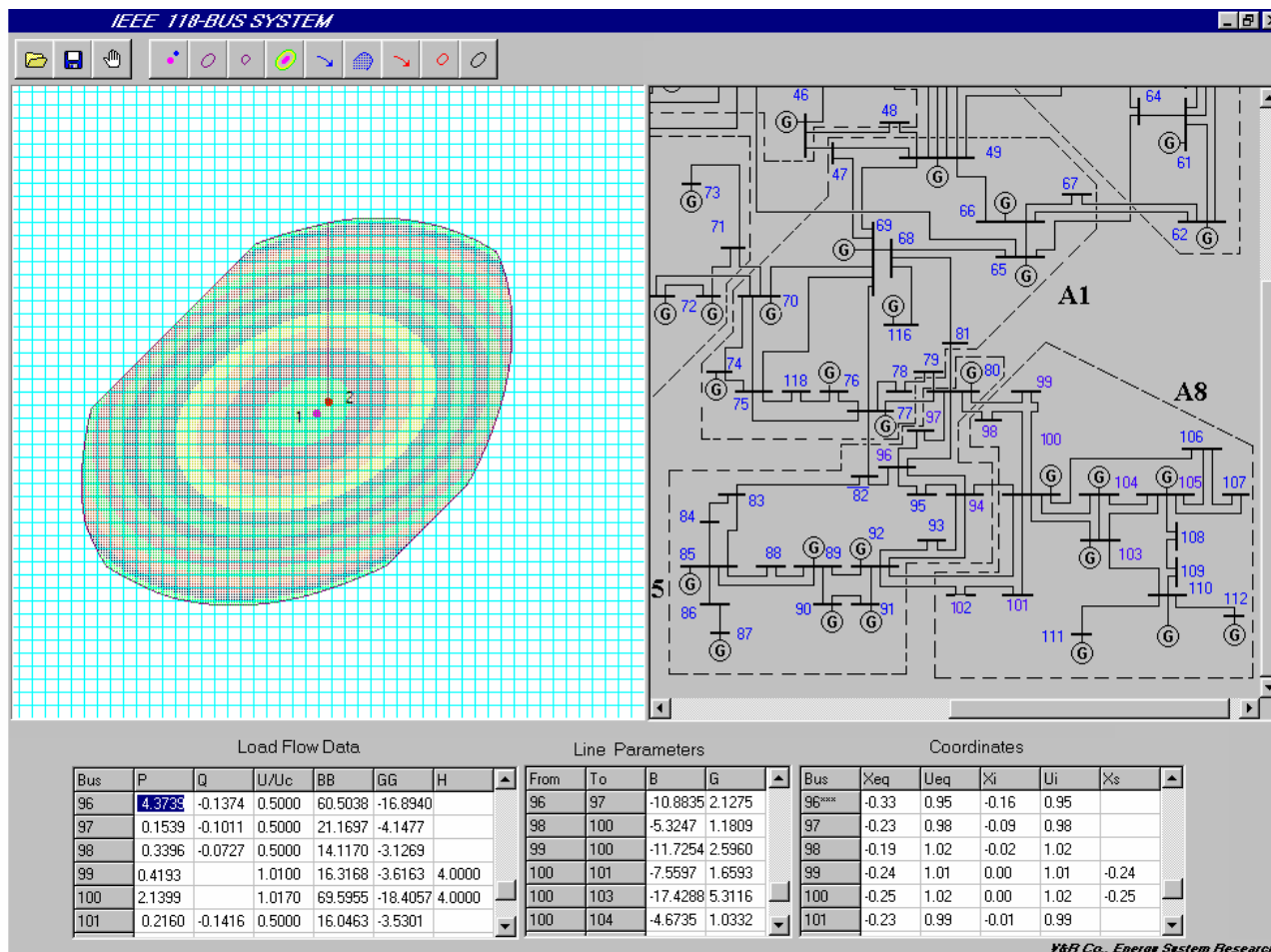


- Monitoring of transient stability violations is added to BOR
- Monitored limits incorporated in BOR-TS are:
 - Transient stability, Steady-state stability, Thermal, Voltage range/drop, Flowgate



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 widespread blackouts while utilizing PMU phasor data





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

8000 Bus System

Scale 150 Vc 0.9 K K1 K2 K3 K4

General Speed tests Renumbering

Buses
 1 (*) 2 (MAX) 3 (MAX)
 54 55 57
 Select buses for K3

Number of Buses 7804
 Number of Lines 9589

V & R Co., Energy System Research

CORONAD1 22 54 1 2 3 All

Bus	P	Q	Vshd/Vmir	5s	Vs	5i	Vi	Links
46 CHOLLA 500.00	0.000	0.000	0.90000	9.30308	1.04745	6.99416	1.04316	45, 47, 48, 49, 57, 208
54 CORONAD1 22.00*	365.000	96.200	0.97500	15.54137	0.97500	0.00000	0.97500	57
55 CORONAD2 22.00**	365.000	96.400	0.97500	15.51717	0.97500	0.00000	0.97500	57
56 CORONADO 345.00	0.000	0.000	0.90000	10.91048	1.03378	7.18826	1.02507	57, 240
57 CORONADO 500.00***	-36.700	-5.200	0.90000	9.73090	1.05488	2.90794	1.05246	46, 54, 55, 56, 223
223 SILVERKG 500.00	0.000	0.000	0.90000	-8.14681	1.03507	-10.12652	1.04047	57, 118, 222

Generators Loads Branches Transformers Shunts in buses Shunts in lines SVDs DC Buses DC Lines DC Converters

Bus	Id	Status	P	Q	Pmax	Qmax	Qmin
54 CORONAD1 22.00	1	1	365.00	96.20	365.00	190.00	-50.00
55 CORONAD2 22.00	1	1	365.00	96.40	365.00	190.00	-50.00