San Francisco Chapter
The Institute of Electrical and Electronic Engineers
Power Engineering Society

The Future of Real-Time Energy Management Systems For Transmission System Operations

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Topics to be Discussed

1. History of EMS Software
2. State Estimation
3. Load Flow Calculations
4. Restoration Plans
5. System Utilization - AGORA
6. Summary, Q&A

- Issues
- State of the Art
- Next Generation

EMS History*

1880
- Energy Management Systems (EMS)

1950
- 1st - System Dispatchers – Manual Tools and Procedures
- 2nd - Mid 1950's – Analog Computers made possible AGC (LFC & ED)

1960
- 3rd – Digital Computers and SCADA, RTUs
- Concurrently – Displays evolved
  - Strip Chart Recorders
  - Annunciator Panels
  - Color CRT's
  - Mosaic Mapboards
  - Projection Displays
- AGC + SCADA = EMS

1970
- **Early 70s - State Estimation Pioneered by Fred C. Schweppe, MIT Professor *(Uncertain Dynamic Systems*, published 1973)**
- Mid 70s – Optimal Power Flow Algorithms Developed (N-R Based)
- 1972 – 10 EMS Control Centers World-Wide

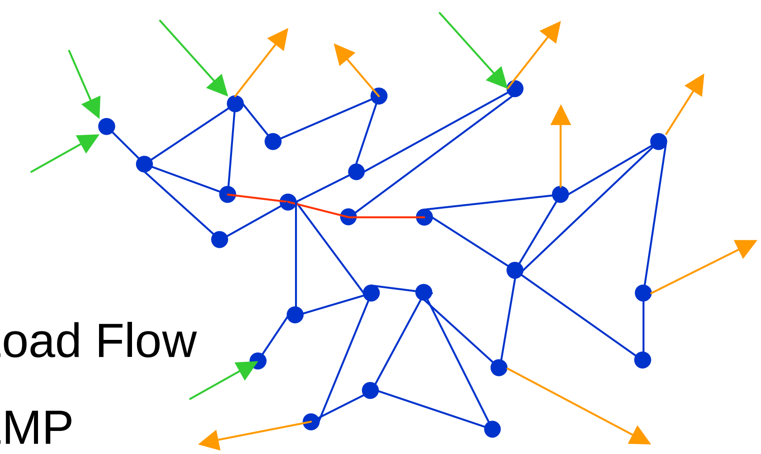
1990
- Today – Over 600 EMS Control Centers

2003
- 1990s – New Load Flow Algorithm – 100% "Convergent"

*"Control Centers Are Here To Stay", T.E. Dy-Liacco, IEEE Computer Applications in Power, Voume 15, Number 4, October 2002

Why State Estimation?

- Financially advantageous to operate near capacity
- Transmission system must be monitored to operate near margins
- Visibility is expensive – CTs, PTs, PMUs, communications, etc.
- Transmission system is too complex to analyze manually
- Many operations and planning engineering tasks require complete system data
  - Contingency analysis
  - Clearance evaluation
  - ATC
- SE output is a primary input to Load Flow
- SE output is a primary input to LMP



State Estimation "State of the Art"

- "Our SE works pretty well, but when we use it for input to our LMP program, we get some crazy results."
- "We started installing it six years ago, our vendor committed to having it running five years ago, we gave up last year."
- "We're pretty sure we'll have it running by the end of this year. Of course, we said that last year, too."
- "We've only got 50% nodal visibility, you need at least (75%, 120%) for a state estimator to work."
- "We've got too many problems with our model. A state estimator will never work here."
- "We spend several engineer-hours each day tuning our state estimator."
- "Our state estimator works great. We have 100% bus visibility."
- "It's the best kept 'dirty secret' in our industry – state estimators don't really work."

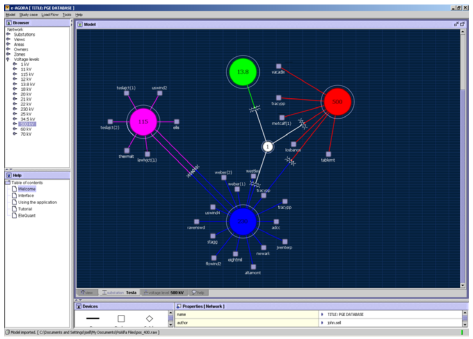
Next Generation State Estimation Solutions

- Import analog data from SCADA system (digital by exception)
  - Topology Check Topology Estimation
  - Analog Data Quality Check *(dynamically assign weights)*
  - Parameter Quality Check Parameter Estimation
- Analog Value Estimation, Minimize Weighted Function (iterative)
- Calculate Load Flow (Complete SE & Verify SE Result)
- Report Results

No Maintenance Required!

The Importance of Load Flow Calculations

- Primary tool for clearance evaluation
- Primary tool for contingency analysis
- Required for transient, dynamic stability studies
- “Base Case” designs for security analysis, transfer capability
- Planning tool for system restoration plans, design analysis
- There isn’t much you can do without performing a load flow calculation



Load Flow Calculations “State of the Art”

- Newton-Raphson iterative mathematics, Gauss-Seidel, et al
- Modified methodologies for different problems, e.g., continuation method
- Solution required for initial starting point
- There are 2^n mathematically correct solutions for every N-R calculation. 2^n -1 of these are incorrect (unrealizable in the physical world)
- Works pretty well in steady-state conditions, doesn’t work at all with large system changes – can be unreliable in real time systems.
- “Craftsmanship” is important to calculation results
- Best suited for off-line applications where trial and error is possible
- Can be very fast (when updating the Jacobian matrix isn’t required . . .)

New Load Flow Calculation Methodology

Mathematical Breakthrough

- Deterministic Calculation Methodology
  - No Starting Point Required
  - No Iterations
  - Always “Flat Starts”
- Guarantees:
  - No “Wrong” Solutions
  - No “Spurious” Solutions
  - If a Solution Exists, (AGORA’s) Load Flow will Calculate It.
- Mathematical Proof Exists, We’ll Tell you How we do it Under NDA.

100% Calculation Reliability for Load Flow!

Restoration Plan Issues

- High volume of information
- Equipment availability
- Unavailability of real-time load flow tools (out of normal range, no convergence)
- Coordination with neighboring utilities
- Transmission disturbances are not frequent but are very complex
- All disturbances are different, therefore every restoration is different

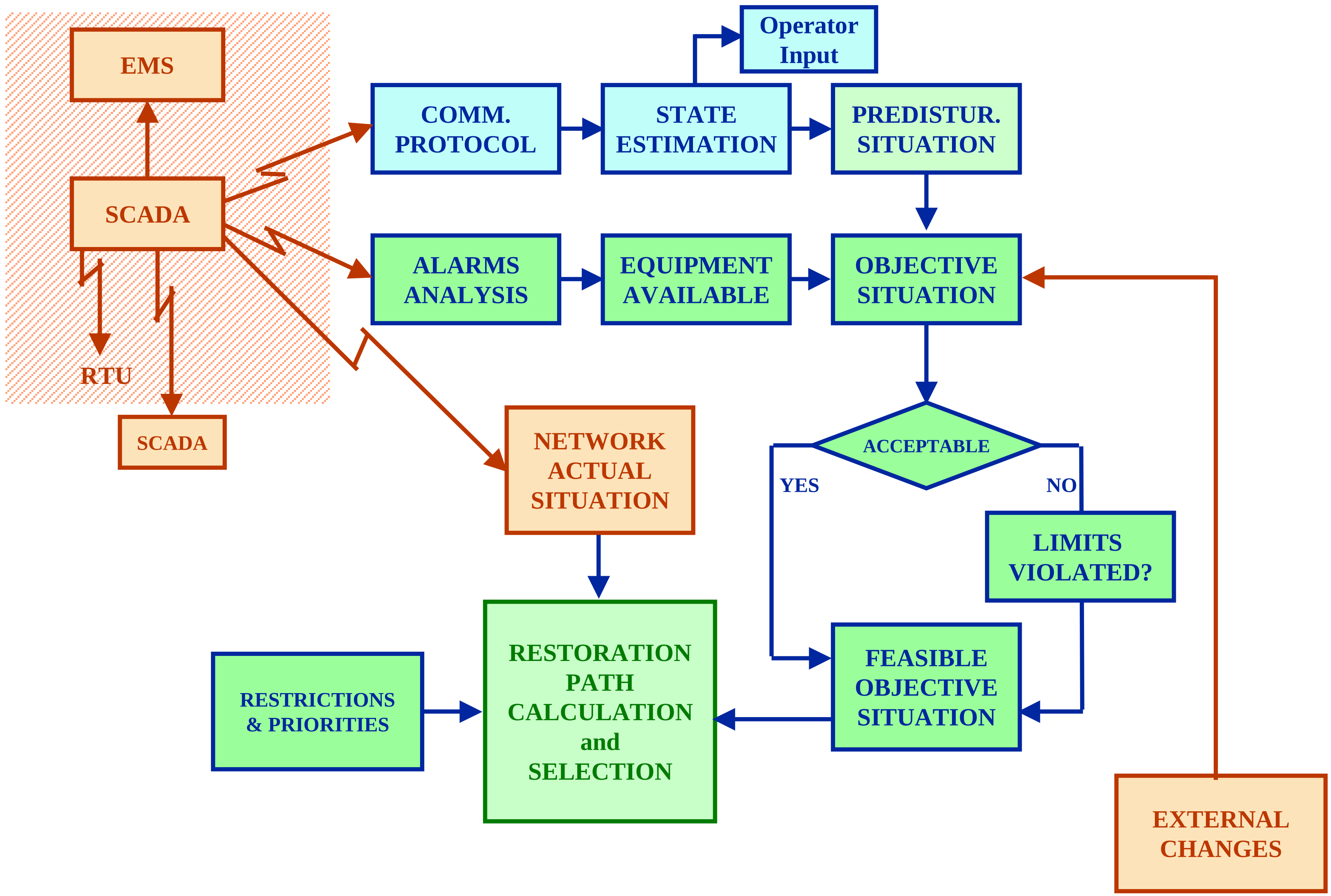
Restoration Plan "State of the Art"

- No special support exists - "a priori" restoration plans only
- Simulation & training support are limited
- Restoration routines developed in operations engineering or planning engineering environment, executed in operations environment
- Effectiveness is largely dependent upon knowledge, experience, and skill of operator(s) on duty

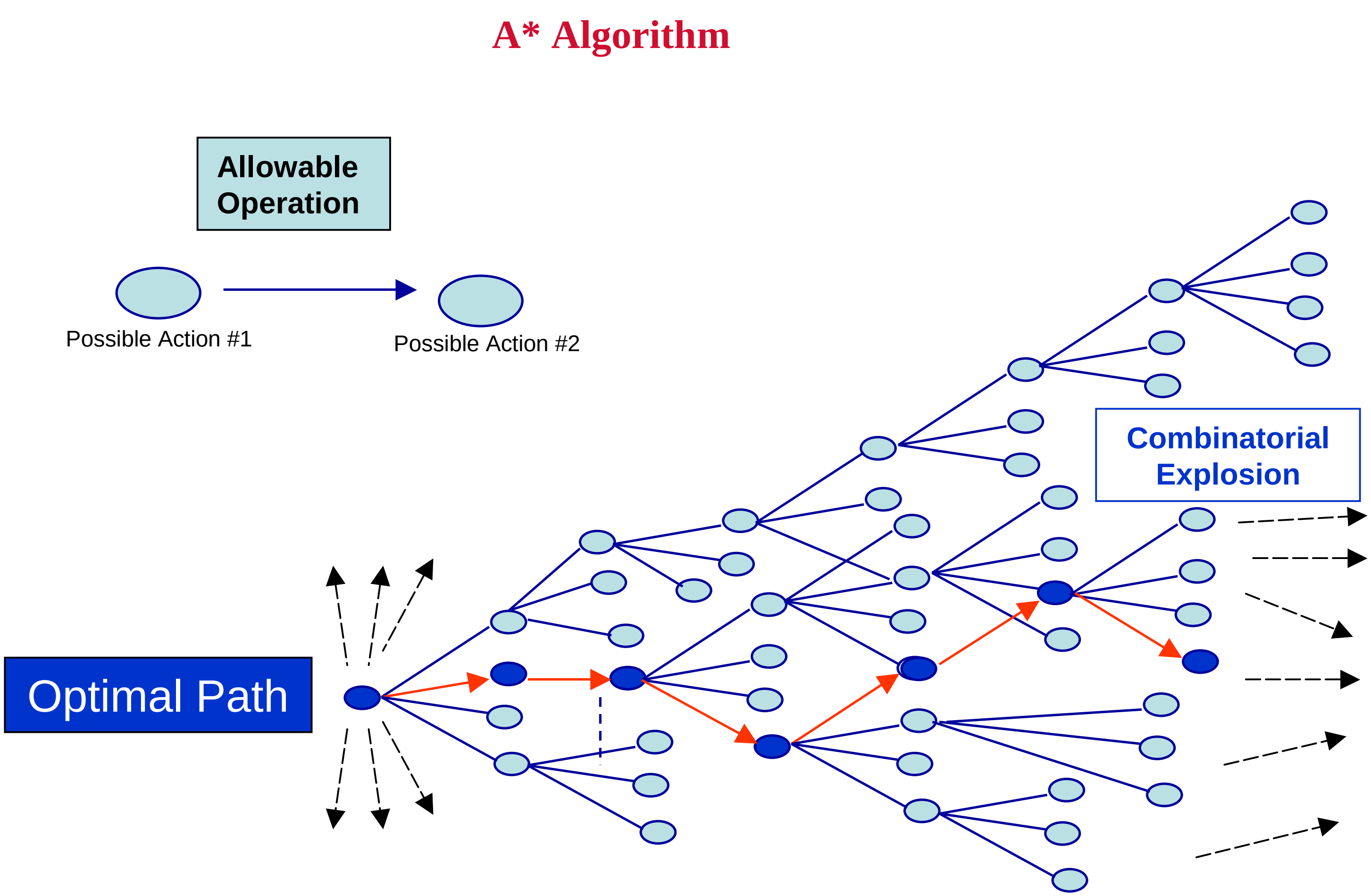
New Restoration Plan Development Methodology

- **Generates Restoration Plans in Real-Time**
  - Utilizes parameters from actual grid conditions
    - Robust State Estimator
    - Load Flow Calculations Through Voltage Collapse
  - Provides step-by-step restoration plans
  - Maintains system limits for restoration
  - Determines the optimum restoration events sequence
  - Incorporates user-defined rules and plans
  - Recognizes and adapts to the situation
    - Restoration steps performed out-of-sequence
    - Dynamically adaptive to new outages/events

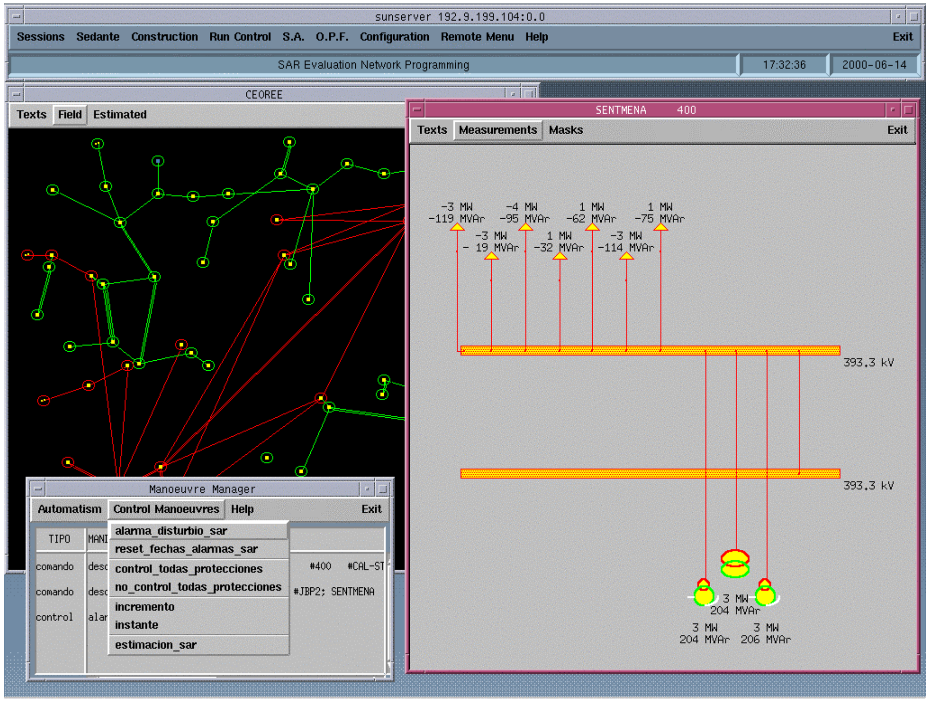
RESTORATION FUNCTIONALITY

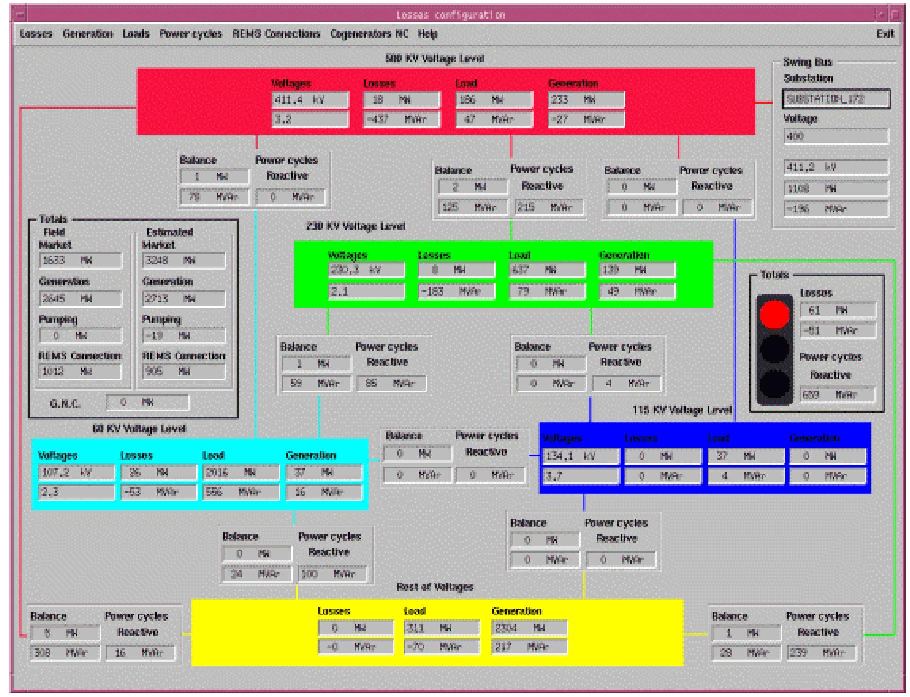


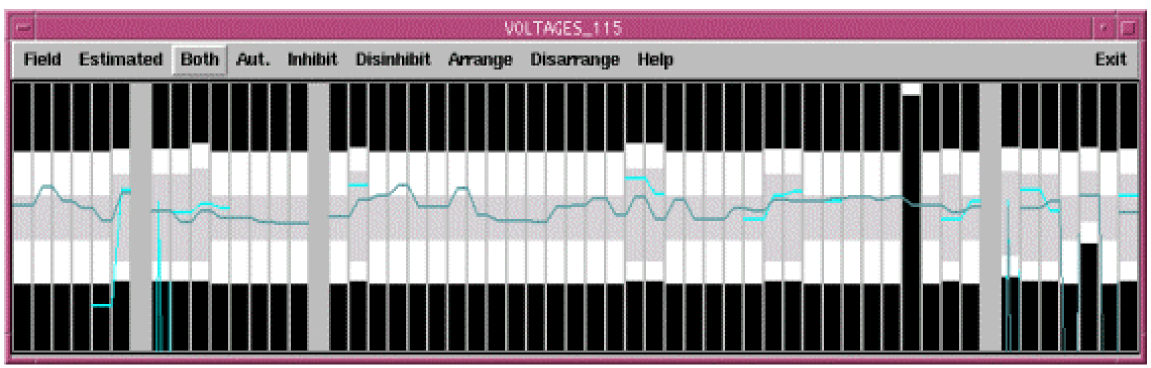
Optimum Restoration Path



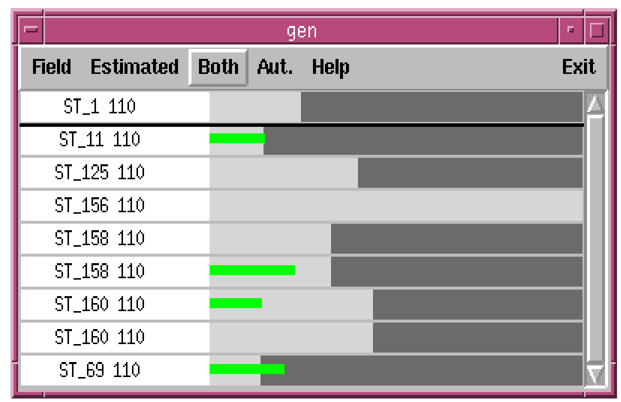
AGORA Applications Interfaces



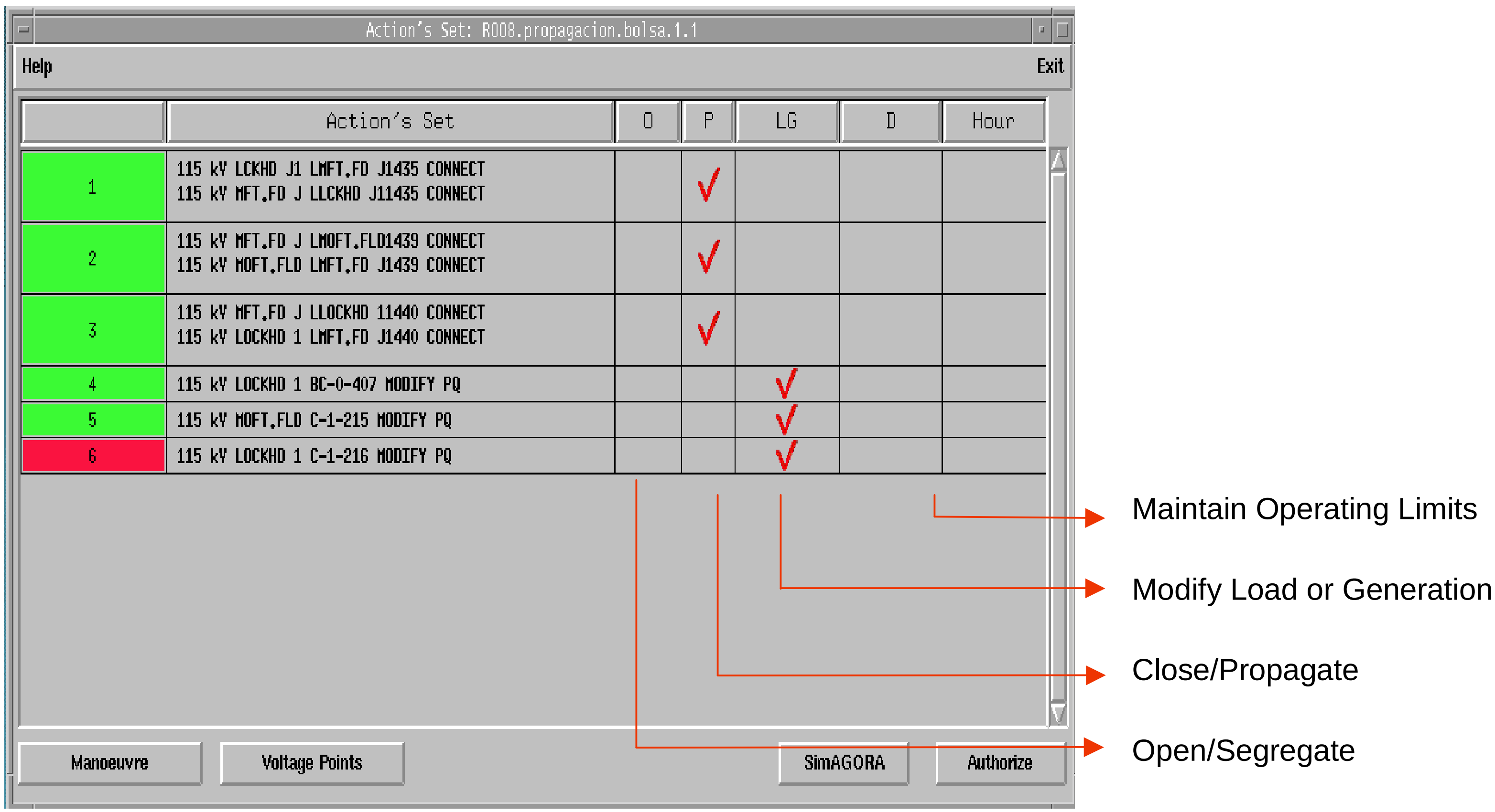




Note: Real Client Displays disguised for presentation purposes



AGORA Applications Interface

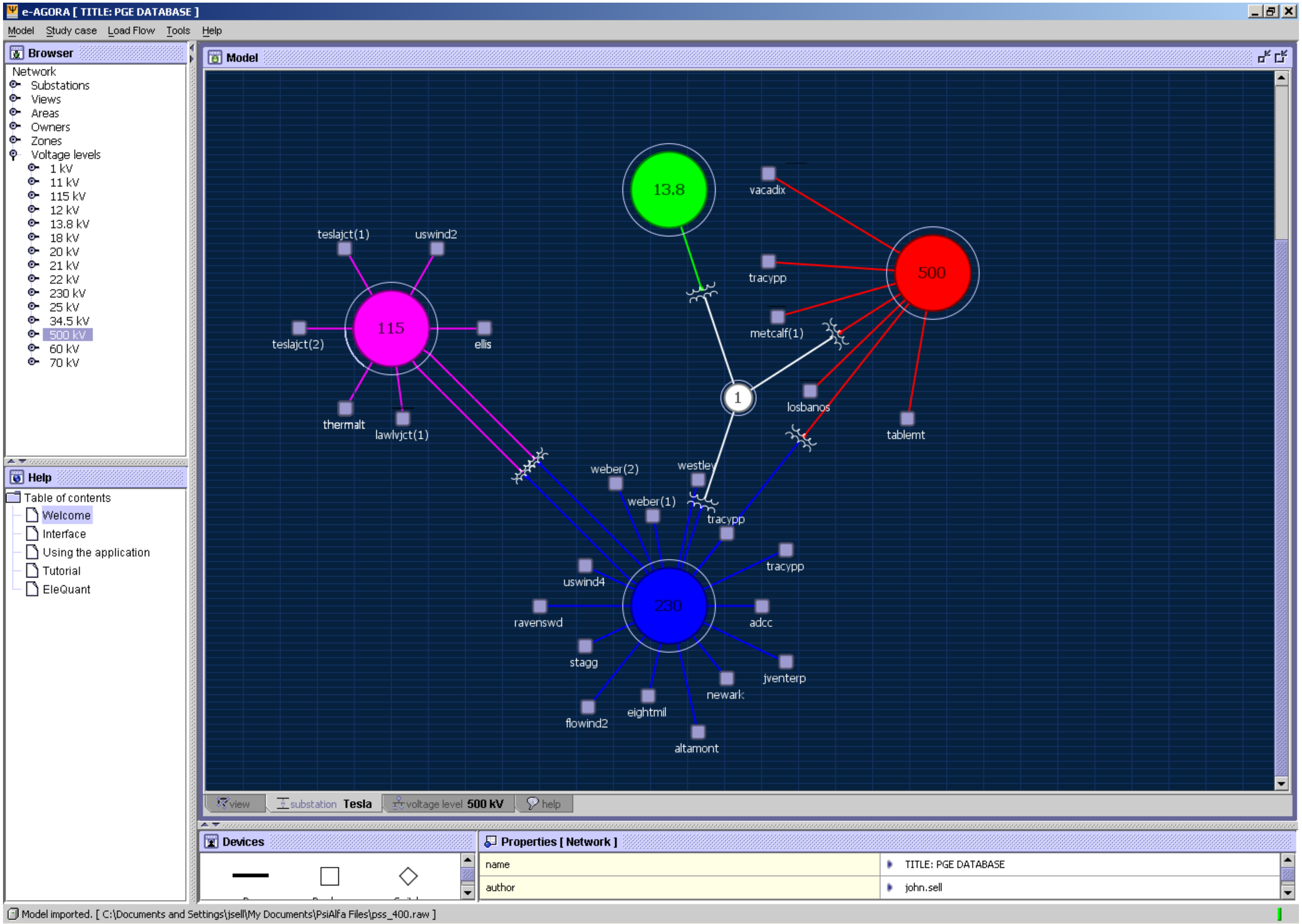


Note: Real Client Displays disguised for presentation purposes

AGORA

- Will interface with any SCADA system
- Will co-exist with other EMS tools (no maintenance required)
- Supports real-time (Operations) and off-line (Operations Engineering, Security, Planning) applications
- On-line and off-line simulation environments (OTS, DTS)
- Installs in months – typically 2-4, total
- First automatic, real-time restoration plan generator for transmission systems

eAGORA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Model Study case Load Flow Tools Help
Browser
Network
Substations
Views
Areas
Owners
Zones
Voltage levels
1 kV
11 kV
115 kV
12 kV
13.8 kV
18 kV
20 kV
21 kV
22 kV
230 kV
25 kV
34.5 kV
500 kV
60 kV
70 kV
Help
Table of contents
Welcome
Interface
Using the application
Tutorial
EleQuant
Model
13.8
vacadix
500
tracypp
metcalf(1)
losbanos
tablemt
1
teslajct(1)
uswind2
115
teslajct(2)
ellis
thermalt
lawlvjct(1)
weber(2)
westley
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ravenswd
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stagg
jventerp
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eightmil
flowind2
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substation Tesla
voltage level 500 kV
help
Devices
Properties [Network]
name
TITLE: PGE DATABASE
author
john.sell
Model imported. [C:\Documents and Settings\jsell\My Documents\PsiAlfa Files\pss_400.raw]

eAGORA

- Imports base cases from existing formats
- Models can be modified or created with drag & drop elements
- When model and parameters are defined, load flow equations are solved on command. Calculations are performed on our server.
- Useful for contingency analysis, planning, clearance evaluation, etc.
- Java-based to run in any software environment
- Solved cases can be re-exported to other formats

Summary

- Transmission system operations can be improved while lowering costs
- Utility customers can benefit from reduced outage time – so can local and regional economies
- Operations and planning tools can be coordinated
- Markets can be better optimized (ISOs)
- Transmission systems can be optimized (RTOs, owners)
- And much more is possible . . . . .

Questions?