Power System Generation Management:
ePHASORsim and ETAP AGC toolbox

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Agenda

• Introduction
• ETAP Presentation
• Demo
• Applications
• More about ePHASORsim
• Questions and Answers
- Who is ETAP
- Products / Solutions
- Customer base
- How Opal-RT and ETAP are working to serve the utility industry
- End-to-End Simulation for GRID applications
Corporate Profile

• More than 200 employees worldwide, most of whom are involved in software development, support, and training.

• The industry’s largest network of offices and support centers with more than 500 sales and support representatives worldwide

• 27 years of growth, and a rate of 25+ % per year
ETAP is a world-class software, services, and solutions delivery organization:

- **ETAP** brings together the industry’s most proven power systems engineering expertise and talented application developers

- **ETAP Automation** specializes in the implementation of ETAP Real-Time™ solutions, as well as value-added power system engineering solutions
Proven Industry Solutions

- Consulting Firms
- Distribution Systems
- Transmission Systems
- Generation Plants
- Oil & Gas Facilities
- Commercial Buildings
- Hospitals

- Mission Critical Facilities
- Data Centers
- Manufacturing Plants
- Government Facilities
- Metals & Mining Plants
- Transportation Systems
- Universities & Education
ETAP is the most proven, integrated suite of software products for the entire lifecycle of electrical power system design and operation:

- **ETAP®**: 50-module power system modeling, design, analysis, and optimization suite
- **ETAP® Real-Time™**: On-line, real-time predictive power system management software
- **ETAP® Grid™**: Enables electrical utilities to plan, coordinate and safely perform power grid operations
Design & Analysis Suite: Robust base modeling package with 50 integrated modules:

- Network analysis (arc flash, load flow, short circuit, motor starting, load analyzer analysis)
- Dynamics & Transient
- Cable Systems
- DC Systems
- Transformer
- Panel Systems
- Device Coordination
- Renewable Energy
- Control Systems
- Ground Grid Design
- Low Voltage Systems
- Distribution Systems
- Transmission Lines
- Power Quality
- Data Exchange/ Conversion
Industry’s most proven platform for real-time power system management, operations and maintenance:

- Power System Monitoring & Simulation (PSMS)
- Energy Management System Software (EMS)
- Substation Automation Management System Software (iSub)
- Intelligent & Fast Load Shedding Software (ILS)
- Distribution Management System (DMS)
- MicroGrid Master Controller (MMC)
Enables electrical utilities to plan, coordinate and safely perform power grid operations:

- Allows users to manage, control, visualize, optimize, summarize and automate power distribution networks
- State-of-the-art Distribution Management System (DMS)
- Powerful integrated GIS capabilities
- Integrates and modernizes existing Supervisory Control And Data Acquisition (SCADA) systems
International Nuclear Users
Brazil, Canada, China, Finland, France, Germany, India, Japan, South Korea, Spain, USA

USA Nuclear Generation Plants
60 out of 64 Standardized on ETAP

97%
ETAP Quality Assurance

- Mature QA Program since 1991
- Complete Software V&V
- Complete Library V&V
- Multiple Audits per Year
- Standards
  - ISO 9001:2008
  - 10 CFR 50, Appendix B
  - 10 CFR 21
  - ANSI/IEEE 730.1
  - ANSI/ASME N45.2
  - ASME NQA-1
  - CAN/CSA-Q396.1.2
  - ANSI N45.22
The Industry’s Standard

• **Global**: 50,000 licenses of ETAP products have been used in power system projects around the world... *far more than any other company in our category.*

• **Trusted**: 5,000 companies, electric utilities, and government agencies in 100 countries worldwide rely on ETAP.

• **Proven**: 100% of the top electrical design firms use ETAP *(source: ECM)*; 80% of these firms have multiple/corporate ETAP licenses

• **User-Driven**: 95% of our software features and functions originate from user suggestions and requests
Consulting Firms & EPC’s

- Bechtel
- Framatome ANP
- Alstom
- Parsons
- PB
c
- Fluor
- Smeprogetti
- AREVA
- JGC
- Duke Engineering & Services
- Technip
- ECI
- Sargent & Lundy
- Brown & Root
- KBR
- Amec
- Worley Parsons
- Tata
- URS
- Shaw Stone & Webster, Inc.
- Foster Wheeler
- Washington Group International
- SNC Lavalin
- Wood Group Mustang
- Schlumberger
- Cegelec Solutions & Services
Government Facilities
Complete Lifecycle Solution

1. Design
   - Rule-Based Driven Design
   - Integrated Analysis Tools
   - Intelligent Modeling
   - Geospatial Layout & Analysis

2. Construction
   - Engineering Schematics
   - Equipment Management
   - Revisions & Version Control
   - Bill Of Materials

3. Commissioning
   - Online Model Validation
   - Work Flow Management
   - Information Management

4. Operations
   - Real-Time Decision Making
   - Energy Management
   - Automation & Optimization
   - Predictive Simulation
   - Intelligent Fast Load Shedding

5. Maintenance
   - Model Change Management
   - Forensic Analysis
   - Power Management Workflow
   - Asset Life Cycle Management
End-to-End Simulation

Hands-on Demonstration
ETAP Real-Time Model View
ETAP Real-Time - AGC View

The 7th International Conference on Real-Time Simulation Technologies
Montreal | 9–12 June, 2014

### AGC View

<table>
<thead>
<tr>
<th>Mode</th>
<th>MW</th>
<th>% Spn Raw</th>
<th>Capacity</th>
<th>kW</th>
<th>Mvar</th>
<th>Freq</th>
<th>p.f.</th>
<th>MW</th>
<th>Mvar</th>
<th>DP</th>
<th>DF</th>
<th>MW</th>
<th>Mvar</th>
<th>%MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area 1 - Area 1</td>
<td>243.74</td>
<td>67.02</td>
<td>738.70</td>
<td>15.75</td>
<td>59.90</td>
<td>-0.96</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Generation**
  - G1: Auto Fall
    - MW: 10.84
    - % Spn Raw: 95.58
  - G2: Auto Fall
    - MW: 133.26
    - % Spn Raw: 49.36
  - G3: Auto Fall
    - MW: 99.51
    - % Spn Raw: 56.35

- **Interchange**

### Load Frequency Control Calculation Status

- Current Status: Last Calculation 11:10:45 AM
- Next Calculation: 11:10:46 AM
- Current Status: Never stated
- Next Calculation: On Demand

### Economic Dispatch Calculation Status

- On Demand

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- **Operating Mode**
  - Supervisory
  - Advisory

- **Current Time**
  - May 27, 2014, 11:20:46 AM

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- **Network Controls**
  - Type: Gen, DeltaF
  - Existing Setpoint: 0.00, -0.75
  - New Setpoint: 0.00, 0.00
  - Status: Implemented, LFC
  - Control: LFC
OPAL-RT Model View
ePHASORsim:
Solution for...
Real-time transient stability simulation
- Real-time simulator
- Linux OS
- Large-scale power system
- Phasor domain

- On-line simulation
- Windows OS
AGC Integrated with ePHASORsim

- ETAP Editor mode
- ETAP Monitor mode
- OPC Server (Kepware)
- AGC App.

- Real-time
- 10 ms time-step
- Linux OS
- NOT Real-time
- 1-5 sec refresh rate
- Windows OS

Get Simulation Results for Display
Get power set-point
Send Generator's:
  - Bus voltage
  - Active power
  - Reactive power
  - Frequency

Convert
Send AGC Ctrl Signals
Get Simulation Results to calculate set-points
Show Time... Live Demo!
Local Control

Controls
- Active Power
- Speed (frequency)

Image source: ETAP
Governor operation principals...

1. Steady State

2. Load Decrease

3. Load Increase
Energy Management System (On-Line)

- Load Frequency Control
- Economic Dispatch
- Interchange Transaction Scheduling

Image source: ETAP
Automatic Generation Control

- Fine tuning of power set-points based on system measurements:
  - Actual generation
  - Operating frequency
Energy Management System (Real-time)

ePHASORsim

Image source: ETAP
AGC Control

Send to AGC
- Terminal voltage
- Power generation
- Unit frequency (speed)

Signals from AGC
- Power set-points
- Dispatch command

Image source: ETAP
ePHASORsim: Solution for... Real-time transient stability simulation
AGC View...
DNP3 and OPC...

- Industrial protocol to transmit data using serial or IP communication
- Data transfer between Master (control station) and Slaves (remote equipment)
- Smart grid metering and remote monitoring
- Energy and power quality meter
- Transmission and distribution network protection and control
What is ePHASORsim?

Real-time transient stability simulator
- Large-scale power systems
- Transmission, distribution and generation

Phasor domain solution
- Nominal frequency
- Positive sequence (balanced systems)
- 3-phase (unbalanced systems)
- Time-step in the range of few milliseconds

\[
\begin{align*}
\dot{x} &= f(x, V, t) \\
0 &= g(x, V, t) \\
x(t_0) &= x_0
\end{align*}
\]

Machines, Controllers, Dynamics + Network side algebraic equations

Discretization of differential equations
- Explicit Euler
- LU Factorization

Solving linear algebraic equations
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ePHASORsim
for Large-Scale Power Systems

Real-time Simulation
Transient Stability
Operator Training Simulator
Test SCADA Systems
Distribution Systems
Parallel Processing
Hardware-In-the-Loop
UDM Simulation
**Simulation time:** 10s, **time-step:** 10ms

**Number of CPU cores:** 1

<table>
<thead>
<tr>
<th>Number of components</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buses</td>
<td>4992</td>
<td>9984</td>
<td>19968</td>
</tr>
<tr>
<td>Generators</td>
<td>1280</td>
<td>2560</td>
<td>5120</td>
</tr>
<tr>
<td>Controllers</td>
<td>2304</td>
<td>4610</td>
<td>9216</td>
</tr>
<tr>
<td>Others</td>
<td>9144</td>
<td>18368</td>
<td>36820</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Computation time (ms)</th>
<th>Normal</th>
<th>Disturbance</th>
<th>Overruns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>1.62</td>
<td>3.28</td>
<td>NO</td>
</tr>
<tr>
<td>Disturbance</td>
<td>3.49</td>
<td>7.43</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>YES</td>
</tr>
</tbody>
</table>
30,000 nodes with 72 partitions

<table>
<thead>
<tr>
<th>Nb of CPU</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>
Questions...?