Business Issues and Computational Challenges in Power System Planning and Operations

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DOE Workshop on Power System Planning and Operations: Computational Challenges for the 21st Century
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Presented by:
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President, Electric Power Group
Founding Member, Consortium for Electric Reliability Technology Solutions
Presentation Outline

- Introduction
- Business Issues
- Computational Models – Historical Perspective
- What Has Changed?
- Planning and Operating Issues – Examples
- Power System Challenges
- Phasor Technology
- Industry Adoption
- Static vs. Dynamic View
- Phasor Data Utilization
- Phasor Real Time Dynamics Monitoring System (RTDMS™)
- Phasor-based Metrics in RTDMS
- Power System Problems and Computational Techniques
- Computational Challenges

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EPG/CERTS Introduction

Electric Power Group, LLC
- Provides management and strategic consulting services for the electric power industry
- Experienced team led by senior executives and managers from the electric industry
- Focus areas include power system planning, policy and strategic assessments, reliability research and technology development, industry and electricity market structure, grid operations and reliability, power technologies, venture investments and start-ups
- Led by Vikram S. Budhraja, Formerly President Edison Technology Solutions and Senior Vice President, Southern California Edison Company with responsibility for Planning, Operations, Transmission and Technologies

Consortium for Electric Reliability Technology Solutions (CERTS)
- Consortium of U.S. Department of Energy national labs, universities, and industry partners; managed by Lawrence Berkeley National Lab
- Supported by the DOE, Office of Electricity Delivery and Energy Reliability, and California Energy Commission, Public Interest Energy Research Program
- Mission Statement – To research, develop and disseminate new methods, tools, and technologies and technology solutions to protect and enhance the reliability of the U.S. electric power system and efficiency of competitive electricity markets
## Business Issues in Power System Planning and Operations

<table>
<thead>
<tr>
<th>Category</th>
<th>Key Issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply</td>
<td>Adequate, Reliable</td>
</tr>
<tr>
<td>Blackouts</td>
<td>Prevent, Reduce Footprints and Duration</td>
</tr>
<tr>
<td>Costs</td>
<td>Reduce Consumer Bills &amp; Societal Cost</td>
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<tr>
<td>Environmental</td>
<td>Reduce Emissions &amp; Carbon Footprint</td>
</tr>
<tr>
<td>Renewables</td>
<td>Integrate Intermittent, Remote, Distributed, Large &amp; Small Renewables</td>
</tr>
<tr>
<td>Infrastructure Investments</td>
<td>Siting, Technology Selection</td>
</tr>
<tr>
<td>Technology Integration</td>
<td>Plug-in Hybrids, Storage, On-site Generation, Microgrids</td>
</tr>
</tbody>
</table>
### Computational Models Used in Power Systems – Historical Perspective

<table>
<thead>
<tr>
<th>BUSINESS ENVIRONMENT</th>
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</thead>
<tbody>
<tr>
<td>Industry Structure</td>
</tr>
<tr>
<td>Planning &amp; Operations Footprint</td>
</tr>
<tr>
<td>Assets</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COMPUTATIONAL MODELS</th>
<th>USES OF MODELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Models</td>
<td>Load Shapes and Characteristics</td>
</tr>
<tr>
<td>Loss of Load Probability</td>
<td>Installed Capacity</td>
</tr>
<tr>
<td>Production Cost Simulation</td>
<td>Resource Mix</td>
</tr>
<tr>
<td>Unit Commitment</td>
<td>Generation Dispatch</td>
</tr>
<tr>
<td>State Estimation</td>
<td>Network Analysis</td>
</tr>
<tr>
<td>Power System Load Flow</td>
<td>Transmission Ratings, Stability Limits, Contingency Analysis, Transients</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MODEL RESULTS USED TO DEFINE ENGINEERING LIMITS AND GUIDELINES FOR PLANNING AND OPERATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-20% Reserve Margins</td>
</tr>
<tr>
<td>N-1, N-2 Transmission Planning</td>
</tr>
<tr>
<td>Static Transmission Ratings</td>
</tr>
<tr>
<td>Nomograms and Remedial action Schemes</td>
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<tr>
<td>Generation Dispatch Guidelines e.g., Imports</td>
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</tbody>
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## What Has Changed?

<table>
<thead>
<tr>
<th>Function</th>
<th>Historical</th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INDUSTRY STRUCTURE</strong></td>
<td>▪ Vertically Integrated</td>
<td>Disintegrated:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Separation of Generation and Transmission</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Separation of Transmission Ownership from Use and Dispatch</td>
</tr>
<tr>
<td><strong>PLANNING</strong></td>
<td>▪ Utility Footprint</td>
<td>▪ Transmission Planning by ISOs with Stakeholder Participation</td>
</tr>
<tr>
<td></td>
<td>▪ Integrated Resource Planning (G, T, DSM)</td>
<td>▪ Generation and Energy Mgmt. – Market or Regulatory Mandates</td>
</tr>
<tr>
<td>** DISPATCH**</td>
<td>▪ Least Cost Based on Utility Models</td>
<td>▪ Market Dispatch – LMP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Multiple Markets – Energy, Capacity, Ancillary Services – 24Hr, 1Hr, 5Min</td>
</tr>
<tr>
<td><strong>TRANSMISSION RIGHTS</strong></td>
<td>▪ Owners Control</td>
<td>Open Access</td>
</tr>
<tr>
<td>** FLOW PATTERNS**</td>
<td>▪ Predictable and Controllable by Utility</td>
<td>Variable – Driven by Market Economics</td>
</tr>
<tr>
<td>** NETWORK RELIABILITY ASSESSMENT**</td>
<td>▪ State Estimation (Utility Footprint) and Engineering Limits and Guidelines</td>
<td>Dynamic Security Analysis</td>
</tr>
</tbody>
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Planning and Operating Issues -- Examples

<table>
<thead>
<tr>
<th>Issues</th>
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<tbody>
<tr>
<td>Resource Adequacy</td>
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<tr>
<td>Inaccurate Models</td>
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<tr>
<td>Frequency Response</td>
</tr>
<tr>
<td>Lack of Wide-Area Visibility</td>
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<tr>
<td>System Dynamic Stress</td>
</tr>
<tr>
<td>Standards and Grid Metrics</td>
</tr>
<tr>
<td>Dynamic Voltage Response</td>
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</tbody>
</table>

Inaccurate Dynamic Models

Lack of Wide-Area Visibility

Declining Reliability Performance Trend

Recent Large Frequency Excursions With Changes Over 3,000 MW

Aug 14, 2003
EI Blackout

Source: www.nerc.com
Angles are based on data from blackout investigation. Angle reference is Browns Ferry.

Electric Power Group
Power System Challenges – Opportunities for New Models to Deliver Value

- Investments -- $2 Trillion by 2030
- Blackouts – 2003 Northeast Blackout Cost $5-10 Billion
- Congestion
  - Annual cost estimated to be several billion dollars
  - DOE’s 2006 National Electric Transmission Congestion Study indicated that “Transmission congestion always has a cost.”
- Market Dysfunction – 2001 California electricity crises cost California consumers billions of dollars
- Power Quality and Reliability – Inadequate power quality and reliability costs businesses $50 to $100 billion annually
- Market Inefficiency – Higher LMP, congestion, and market power result in higher consumer costs. $1/MWh LMP improvement is $4 Billion/year
- Asset Utilization – Transmission limits below physical limits. Southern California gateways 20,000 MW vs. limit of 10,000 MW
- Renewables Integration – 300,000 MW of wind by 2030 (33 to 50% RPS)
- Customer Technologies – Millions of PHEV’s, Thousands of MW of Roof Top PVs

Current Models Inadequate – Need New Models for Planning, Operations and Tools and Technologies For Dynamic Grid Management
Phasor Technology – Opportunity to Advance Computational Methods for Power Grid Planning and Operations

- Phasor Measurement Units – Mature Hardware, Networks Evolving and Applications Being Developed
  - Supplements 4-second scan rate of current SCADA technology with higher resolution scans (e.g., 30 samples per second)
  - GPS time stamping enables synchronization of data from multiple sources spanning an entire interconnection
- Provides MRI Quality Visibility of a Power System Compared to X-ray Quality Visibility from Traditional SCADA
- Industry Adoption Underway
  - Phasor deployment expanding in Eastern, Western, and ERCOT Interconnections
  - North American SynchroPhasor Initiative (NASPI) transitioned to NERC
Industry Adoption of Phasor Technology

Wide-Area Measurement Systems - WAMS
- PMUs
- PDCs

Local Data Collection & Event Analysis
- BPA
- SCE
- AEP
- PG&E
- NYPA
- ALBERTA

Starter Phasor Network – Local and Wide Area Data Networking & Monitoring
- WECC – CAISO, BPA, SCE, PG&E, WAPA
- EIPP
- NASPI
- ERCOT
- Et al

Phasor-Based Applications - Research, Demonstrate, Field Trials, User Acceptance
- Visualization
- Monitoring
- Forensic Analysis
- System Dynamics

Use of Phasor Data in Modeling
- Dynamic Ratings
- State Measurement
- Model Validation
- Interconnection Wide Network Models
- Adaptive Controls
- Measurement Based Dynamic Network Mgmt.
- Oscillation Detection & Control
- Pattern Detection & Corrective Actions

60’s - 80’s  90’s-2000  2000  2008  2009
Static vs. Dynamic View

PDCI blocked / restarted FOUR times

SCADA Visibility
(1 sample every 2-4 seconds)

PMU Visibility
(30 samples every second)

2700 MW generation drop & associated oscillations visible
Phasor Data Utilization to Plan and Operate the Modern Grid

- Wide Area Real Time Interconnection Monitoring and Visualization
- Real Time Wide Area Situational Awareness
  - Precursors of Grid Stress e.g., Phase Angles, Damping
- Monitoring of Key Metrics and Standards Compliance
- Translation of Data and metrics into Information Dashboards for Operator Action
- Model Validation (Dynamic Models, Load Models)
- Event Analysis and Forensics
- Small Signal Stability Monitoring and Oscillation Detection
- Automated Control Actions – Smart Switchable Network
- Define “edge” and Reliability Margins – Real Time Dynamic Management
- Compute Sensitivities and Analyze Contingencies
Phasor-Real Time Dynamics Monitoring System (RTDMS)

GAUGE
Quantifies the worst performing metric

LOCATION INDICATORS
Provides information for specific locations or jurisdictions

TRAFFIC LIGHTS
Provides status of specific metrics across the interconnection
Phasor Based Metrics Monitored in RTDMS

...detect Grid Stress (angle of separation)
...detect Dangerous Oscillations (low damping)
...detect Frequency Instability / Islanding
...detect Generator or Line Trip conditions
...detect Low Voltage (Instability) conditions
...determine System Norm or Baseline
# Power System Problems and Computational Techniques

<table>
<thead>
<tr>
<th>Problem</th>
<th>Computational Techniques</th>
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<tbody>
<tr>
<td>State Estimation</td>
<td>▪ Nonlinear Least Squares</td>
</tr>
<tr>
<td>Power Flow</td>
<td>▪ Nonlinear Algebraic Solvers (Newton-Raphson)</td>
</tr>
<tr>
<td>Unit Commitment</td>
<td>▪ Dynamic Programming</td>
</tr>
<tr>
<td>Security-Constrained Optimal Power Flow</td>
<td>▪ Nonlinear Optimization (Gradient Method, Interior Point Method)</td>
</tr>
<tr>
<td>Voltage Stability Analysis</td>
<td>▪ Parameterized Continuation Techniques (Predictor-Corrector Method)</td>
</tr>
<tr>
<td>Transient Stability Analysis</td>
<td>▪ Numerical Integration (Euler’s Method) Energy or Direct Methods</td>
</tr>
<tr>
<td>Small Signal Stability Analysis</td>
<td>▪ Eigen Analysis</td>
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Computational Challenges

- Larger Footprint - Interconnection Wide Network and State Estimation Models
- Dynamic Analysis – Static vs. Dynamic Ratings, Remedial Actions, Nomograms
- Large Volumes of Data - Use of Measurements vs. Estimates
- Dynamic Solutions (Real Time) to Detect Operating Anomalies and Contingencies
- Automated Control Actions
- Tracking the “Edge” Dynamically -- Operating with “Known” Margin from the Edge vs. Static Limits