A Challenge Problem: Grid Operation with Emerging Dynamics and Uncertainties

Henry Huang
Chief Engineer/Team Lead
Pacific Northwest National Laboratory
Challenges in future power grid operations

“Grid evolution meets information revolution”

• **Grid Evolution** – stochastic & dynamic
  – Generation: intermittent renewable energy, distributed generation
  – Demand: smart loads, plug-in hybrids
  – Other: storage, new market design/incentives

• **Information Revolution** – data rich but information scarce
  – Large number of phasor measurement units, smart meters, and intelligent devices
  – Requirements of cyber security
Trend of frequency variance

- Traditional state estimation does not accurately capture the system’s dynamic status
  - During emergency situations, frequency is significantly off nominal 60Hz
  - During normal operation, frequency tends to deviate more often from 60Hz
Larger impact of new and traditional uncertainties

- New uncertainties need to be understood and characterized
- Reduced operation margins tolerate less uncertainties

Credit: Yuri Makarov, PNNL
**Challenge:** predictive grid operation with dynamics and uncertainties

1. Model building considering Transmission + Distribution, >10x larger equations
2. Data technologies to enable >100x faster ingestion and retrieval speed
3. Dynamic state estimation (model + data assimilation) from seconds (SCADA) to subseconds (phasor)
4. Efficient “N-a” contingency analysis considering mixed discrete (topology changes) and continuous (wind deviations) events with probability distribution
5. Look-ahead dynamic simulation >10x faster than today’s tools
6. Small signal stability >10x faster
7. Voltage stability analysis >100x faster
8. Risk-based probabilistic decision making to handle >100x more information within the same or shorter operation cycle

**Diagram:**
- Distribution
- Transmission
- Model
- Measurement (SCADA/Phasor)
- “N-a” Contingency Analysis Framework
- Transient Stability (DAEs)
- Small Signal Stability (DAE Eigenvalue)
- Voltage Stability (PF Eigenvalue)
- Risk-based Probabilistic Decision Making

**Notes:**
- DAE: Differential Algebraic Equations
- PF: Power Flow
Suggested breakout discussions

• (30 minutes) Refine the challenge problem

• (75 minutes) Envision a solution
  – Candidate workflow of an operational solution
  – Key sub-problems associated with the workflow or key integration problems in delivering the workflow
    • Data requirements
    • Computation requirements
    • Visualization requirements
    • Interoperability of software modules
  – Technology assessment: what is in use, what is in research, what is a gap, where are the risks

• (30 minutes) Measure successes
  – Metrics for workflow and sub-problems: how do we measure success
Questions?