U.S. DEPARTMENT OF ENERGY

Office of Electricity Delivery & Energy Reliability

Advanced Grid Modeling for 21st Century Challenges

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Challenges

- Modern-day demands on the U.S. electricity grid have required the introduction of smart devices to improve resilience and reliability in the face of changing grid characteristics and dynamics such as an increase in renewables, electric vehicle integration, changing load patterns, changing flow, and faster performance speeds.
- As a result, today's grid produces an enormous amount of data and a significant challenge is how to enable grid operators to make sense of such a large quantity of grid state and customer data in near-real time.
- Today's technologies, tools, and techniques are not presently up to the challenge.

What is Needed & how to Achieve it?

- **Develop advanced computational (software) and control technologies (hardware) to improve the reliability, resilience, and efficiency of the nation's electricity systems**
- **Help prevent blackouts and improve reliability by providing wide-area real-time visibility into the conditions of the grid**
  - Track and expand the use of real-time data in grid control rooms and energy management systems
- **Build the technology to manage and control future grid operations**
  - Improve the performance of modeling tools and computations that are the basis of grid operations
- **Assess and mitigate near- and long-term risks to energy infrastructures and systems**
  - Track and expand the use of quantitative risk and uncertainty methods in Federal and state-level energy system decisions regarding energy infrastructure investment

Advanced Grid Modeling Program

AGM Develops the Core Operational and Planning Components Supporting the Future Grid

Advances the computational and mathematical methods underpinning operator tools

Seeks to develop "faster than real time" analytical tools through work in three main areas

- Data management and analytics
- Mathematical methods and computation
- Models and simulations

Main Areas

- **Data management and analytics (DM&A):**
  - These activities focus on the way data is collected, used, stored, and archived to improve applicability of large, multi-source datasets for real-time operations and off-line planning studies.
- **Mathematical Methods & Computation (MM&C):**
  - Effort addresses emerging mathematical and computational challenges arising in power systems, developing new algorithms and software libraries.
- **Models & Simulations (M&S):**
  - Research on a new class of fast, high fidelity capabilities that underpin better grid operations and planning in a large-scale, dynamic and stochastic environment.

Current Projects

- Developing GridPACK, an open source HPC library, It includes functionality such as Power Flow, Dynamic Simulation, Power Flow Contingency Analysis, and Dynamic Security Assessment

- Developing Power System Parallel Dynamic Simulation Framework for Real-Time Wide-Area Protection and Control

- Developing Management & Optimization of VARs for Future Transmission Infrastructure with High Penetration of Renewable Generation

Current Projects

- **Developing Probabilistic Methods for Electric Grid Operations**

- **Refining the MMWG models by modeling governor deadband and adjusting active governor ratio and load composition in order to match up measured EI frequency responses. This will help with validating power system dynamic model that is used to perform contingency analysis.**

- **Developing Dynamic Models for Year 2030 Eastern Interconnection**

Current Projects

- Developing State Estimation that can run at a unprecedented 0.5 s speed.
- Developing Dynamic Contingency Analysis tools (DCAT)
- Integrating Planning Dynamics and system Protection simulations models in Computer aided protection engineering tool (CAPE) that allows performing a more accurate analysis of the behavior of protection equipment during the first cycles after a fault condition.

GMLC

DOE announced funding in January, 2016 of up to $220 million over three years for DOE's National Labs and partners.

The Grid Modernization Laboratory Consortium (GMLC) funding will support critical research and development in the AGM Subprogram. The concentration is in:

1. Load Modeling
2. Protection
3. Solvers

GMLC AGM Projects

- **Load Modeling:**
  - Contribute towards development and validation of mathematical model structures capturing emerging load dynamic behaviors.
- **Protection:**
  - Enhance protection system (misoperation) modeling capabilities, as a platform for the study and coordination of protection devices and approaches.
- **Solvers:**
  - Create, maintain, and enhance a scalable math solver library for grid planning and operations tools that work on a variety of computational platforms.

National Academies of Science, Engineering, and Medicine (NAS)

DOE commissioned National Research Council (NRC) to engage in a study with the following charge:

- **What are the critical areas of mathematical and computational research that must be addressed for the next-generation electric transmission and distribution (grid) system?**
- **Identify future needs.**
- **In what ways, if any, do current research efforts in these areas (including non-U.S. efforts) need to be adjusted or augmented?**

Findings

1. Analyze the vast amount of data coming to control centers and represent the results in a way suitable for timely decision making.

2. Improve modeling of grid operation.

3. Advances in the mathematical and computational algorithm are needed to address the challenges arise from the integration of more alternative energy sources into the system as well as to help reduce the risk of voltage collapse and enable lines to be used within the broader limits, and flexible ac transmission systems and storage technology can be used for eliminating stability-related line limits.

Findings

4. Establish a more complete models that include the dynamic interaction between the transmission and distribution systems.

5. Establish a better planning models for accurate forecasting to deal with uncertainties (such as distributed-generation technologies, climate change, shifting rainfall, frequency of intense weather events, changes in policies to reduce emissions of carbon dioxide)

6. Establish a modeling and mitigation plans for high-impact, low-frequency events.

NAS Recommendations

- Make data available for testing
- Create synthetic data for development, testing and validation
- Advance the ACOPF
- Research on Data driven approaches applied to the operations, planning and maintenance of power systems.
- Improve the nonlinear, nonconvex optimization algorithms
- DOE and NSF should sponsor the development of new-open source software for research community
- Promote collaboration between national labs and universities
- Integration of theory and computational methods should be a high-priority research area
- DOE should support research to extend dynamical systems theory and associated numerical methods to encompass classes of systems that include electric grids

Summary

AGM program intends to enhance reliability and enable advanced mitigation and recovery strategies, by:

- **Accelerating performance**
- **Developing predictive/corrective decision-support capabilities**
- **Integrating model platforms**

Question