U.S. DEPARTMENT OF ENERGY

Office of Electricity Delivery & Energy Reliability

Advanced Grid Modeling

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Today's Grid

- Increase in electricity demand in recent years
- Environmental Regulation (Generation and Transmission)
- Aging infrastructure and work force
- Reliability Standards
- Electricity Market
- Lower system inertia
- Intermittent generation and Distributed Energy Resources results in stochastic and dynamic behavior in the system
- ….

Challenges

- 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.

- Utilities operates closer to the limits with a greater level of uncertainty as before

- Today's technologies, tools, and techniques are not presently up to the challenge to manage the uncertainty.

Addressing Challenges

- To address these challenges;
  - A new faster computational and analytical algorithms is needed that can assist operators in information gathering, analyzing, and processing so the actionable tasks can be developed and executed in a timely manner to ensure the reliability, resiliency, security, and efficiency of the Electric Power Grid

Advanced Grid Modeling Program

- Advanced Grid Modeling (AGM) Program leads R&D aiming to transform data to enable preventive actions rather than reactive responses to grid conditions.

- This aims to improve the reliability, security, and flexibility of the system.

AGM Objectives

- Direct the development of advanced computational (software) and control technologies (hardware) to improve the reliability, resiliency, and efficiency of the nation's electricity systems

- Prevent blackouts and improve reliability by providing wide-area real-time visibility into the conditions of the grid

- Improve the performance of modeling tools and computations that are the basis of the grid operations

AGM

- AGM will achieve these objectives by:
  - Advancing the computational and mathematical methods underpinning operator tools and developing “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**
  - 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**
  - Effort addresses emerging mathematical and computational challenges arising in power systems, developing new algorithms and software libraries.
- **Models & Simulations**
  - 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.

Partners

- Projects are planned, coordinated, and implemented in concert with partners from:
  - Other Federal programs
  - Electric utilities
  - Equipment manufacturers
  - Software companies
  - Regional, state, and local agencies
  - National laboratories
  - Universities

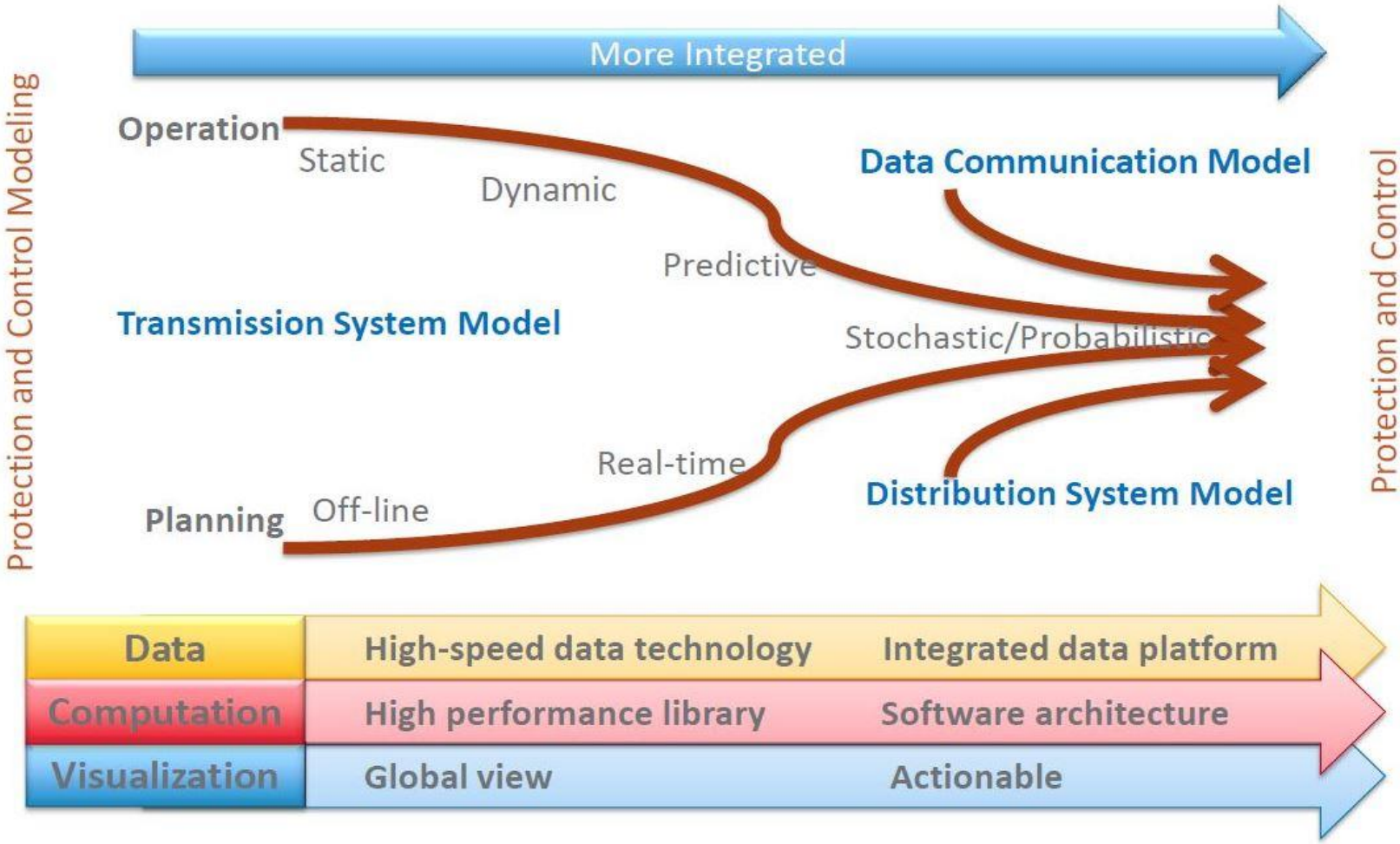
An Example

- Modern power systems are moving toward a stochastic environment due to increase in random forces that modify the system behavior (variable generation, demand-side management, congestion, system load, outages, and market).

- The existing deterministic operational practices are based on established dispatches and flow patterns which are becoming inadequate to deal with this uncertainty problem.

- This could potentially result in an increase in the system failure and outages.

An Example (Courtesy of PNNL)



An Example

- A new generation of stochastic/probabilistic methods, reliability and performance criteria, tools, and business practices is very much needed to deal with this uncertainty.

- Development of effective applications requires research on measurements and data analytics, as well as mathematics and models

Sample of AGM Projects

- Developing State Estimation that can run at a unprecedented 0.5 seconds speed using medium size utility data.

- Developing Dynamic Contingency Analysis tools (DCAT) partnering with ERCOT, Siemens PTI, and EPRI

- 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.

Sample of AGM Projects

- Refining the Multiregional Modeling Working Group (MMWG) models by modeling governor dead-band and adjusting active governor ratio and load composition in order to match up measured Eastern Interconnection (EI) frequency responses. This will help with validating power system dynamic model that is used to perform contingency analysis.

- Developing GridPACK which is an open source HPC library makes math and computing advancements that includes functionality such as Power Flow, Dynamic Simulation, Power Flow Contingency Analysis, and Dynamic Security Assessment (contingency Analysis with dynamic simulation)

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

Sample AGM Projects

- Develop Dynamic Models for Year 2030 Eastern Interconnection
- Developed Management & Optimization of VARs for Future Transmission Infrastructure with High Penetration of Renewable Generation (MOVARTI) which is an integrated VAR analysis and planning tool
- Probabilistic Methods for Electric Grid Operations using Chance Constrained Optimal Power Flow
- Integrated Modeling Platform for Power Grid Computing, Data Management & Visualization
- …..

Grid Modernization Laboratory Consortium

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

GMLC AGM Projects

- **Load Modeling:**
  - Load Modeling contribute towards development and validation of mathematical model structure capturing emerging load dynamic behaviors.
  - Research is required to develop physics, math, and economic (if applicable) representations suitable for analytical assessments that run on a range of computational platforms from desktop.

GMLC AGM Projects

- **Protection:**
  - Enhance protection system modeling capabilities, as a platform for the study and coordination of protection devices and approaches.
  - Applications could include regional system concerns (e.g., cascading event mitigation, special protection systems/remedial action schemes) or local objectives (e.g., feeder-level adaptive protection, intentional islanding/microgrids).

National Academies of Science, Engineering, and Medicine

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?

NRC's Recommendation #8

- The Department of Energy **(DOE)** and the National Science Foundation **(NSF)** should sponsor the development of new open-source library of simulation software intended for the next-generation electric grid research community.

Recommendation (Open Source Software)

- The open source software should include new analytics for the planning and operation of the fast evolving power grid.

- The open source software should also include new mathematical and computational algorithms.

NSF & DOE MOU

- The Memorandum of Understanding (MOU) between National Science Foundation (NSF) and Department of Energy (DOE) establishes the terms under which the NSF's Division of Mathematical Sciences (DMS) and the DOE's Office of Electricity Delivery and Energy Reliability (OE) intend to invest in fundamental mathematical and statistical algorithms to enhance the reliability, resilience, security and efficiency of the electric power grid.

Summary – Future Work

- Define the uncertainties in the future and how they interact with each other. Identify which one should be dealt with first and how.

- Explore how can the research on measurements, data analytics, mathematics, and models be brought together to fully address the dynamic and uncertainty behavior of the system

- Manage the risk for a better grid operations and planning in a large-scale, dynamic, probabilistic, and stochastic environment

- Manage the uncertainty associated with the Data, Modeling, & model validation and how it can be addressed so the proper set of data and model is processed, developed, used, and tested.

Thank You