Technology Session 6: Computational Challenges

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Introduction

- The future grid must reach higher levels of Economy and Reliability (traditional objectives).
- At the same time the future grid has new objectives: Sustainability and Energy Security
- Meeting these objectives results in difficult and new computational problems:
  - Existing tools exhibit fundamental limitations.
  - PMU, AMI, and IED data provide great opportunities for improved industry processes:
    - Must organize and secure the data.

Introduction

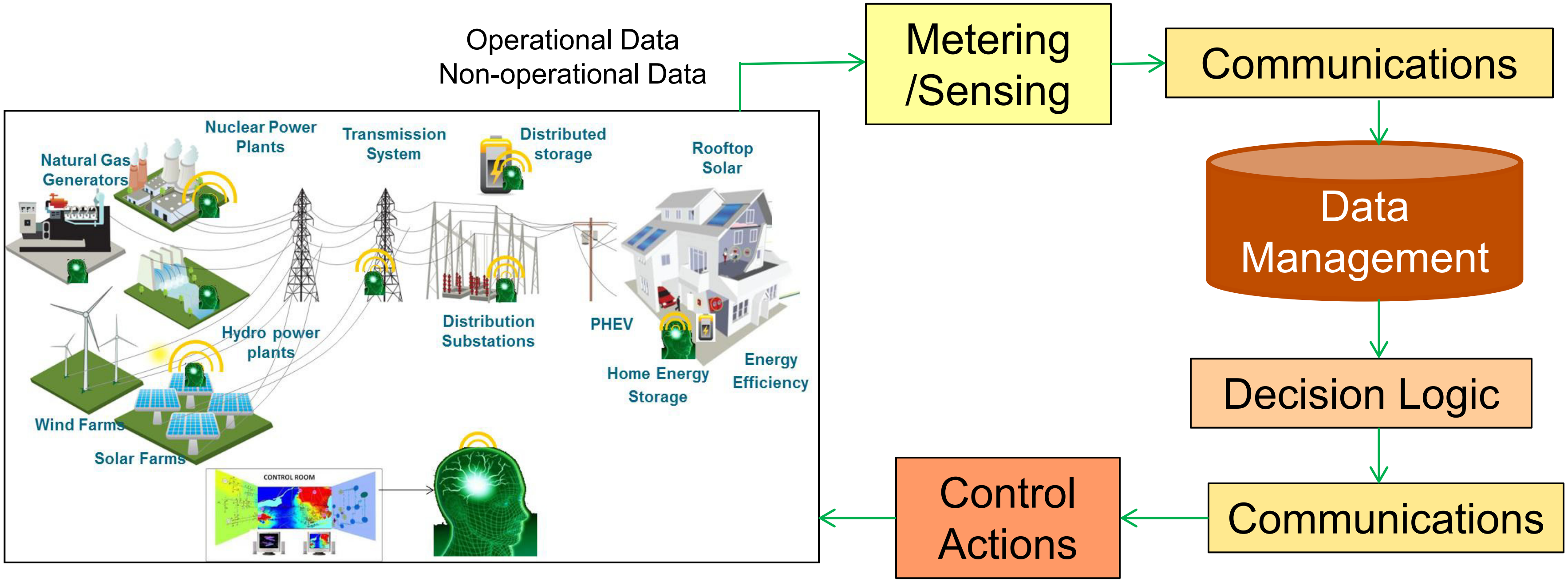
- Thrust Area 5 addresses the ***computational challenges*** of the future grid.
- Computation is critical to the industry because it supports decision-making.
- New decision-making:
  - Spans new scales in space and time.
  - Takes place in a distributed form.
  - Cannot be achieved just by having more data
  - Cannot be achieved just by using more computing power.

Objective

- To develop a ***computational framework*** and ***key algorithms*** that enable meeting the future grid objectives by:

a) Supporting complex and integrated decision-making under uncertainty.
b) Enabling real-time distributed control
c) Leveraging sensing and massive data, and
d) Leveraging advanced computing hardware

Opportunities



Operational Data
Non-operational Data

Metering /Sensing

Communications

Data Management

Decision Logic

Communications

Control Actions

- Major benefits can be achieved if emerging and legacy data is integrated in a seamless framework.
- Decision-making must capture emerging complex phenomena present at new temporal and spatial scales.

Technologies and Opportunities

Technology	Time Scale	Space Scale	Opportunities
Sensing			
Intelligent Distributed Sensor Networks	sec, min	T/D	Ubiquitous low-cost sensing Energy harvesting-powered
Intelligent Electronic Devices	us – min	T/D	Synchronized event recording Operational @ non-oper. data Customizable applications
Smart meters	sec, min, hour	Customer	Consumer-in-the-loop enabler Enhanced restoration
Data Management			
Common Models	-	T/D	Seamless data exchange
Data Mining	all	all	Learning from the load Behavior Discovery

Technologies and Opportunities

Technology	Time Scale	Space Scale	Opportunities
Decision Making			
Data Analytics	min, hour	all	System discovery
Hierarchical control	sec, min, hour	Utility, microgrid, customer	Coordinated control Increased operational range Increased reliability and economy
Model-less phasor measurement security apps.	ms-sec	Wide-area ISO, utility, microgrid	Increased wide-area awareness Enhanced reliability
Rolling Time Stochastic Optimization	LT Planning	ISO, utility	Efficient scenario analysis Increased benefits from assets Optimal expansion planning
Decision-Making Frameworks	all	all	Develops formalisms for decisions Ensures objectives can be met.

TA5

TA5.1 Computational Issues of Optimization for Planning

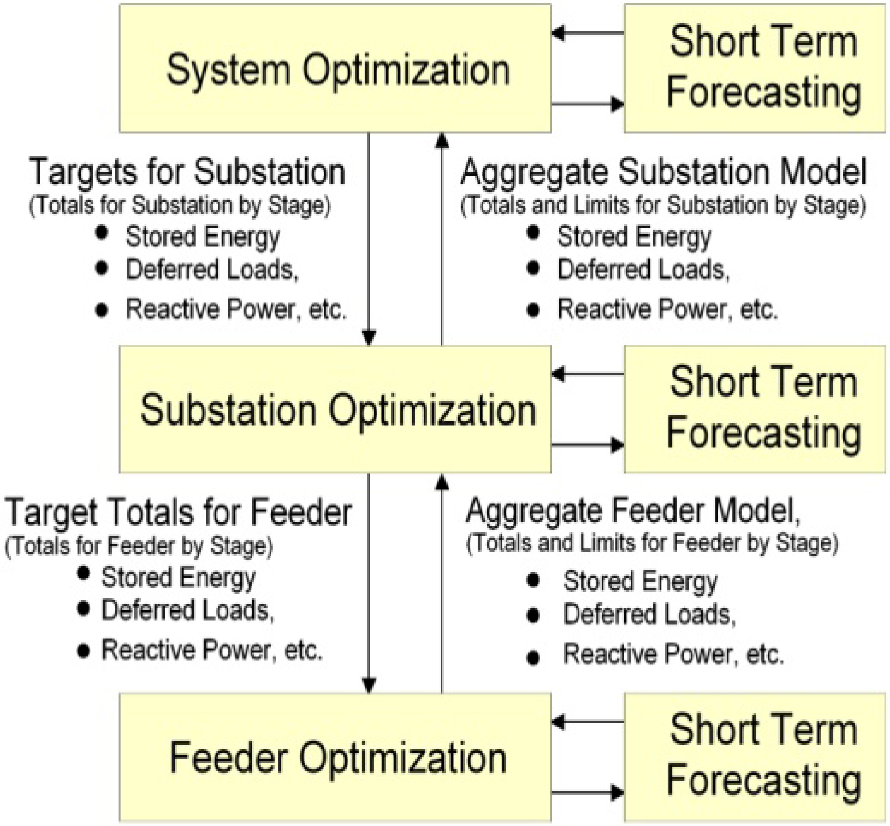
- Task Leader: Sarah M. Ryan, Iowa State University
- Specific Problem to be Addressed:
  - Need for planning tools to accommodate increasing uncertainty and the associated risks posed by high levels of renewable resource penetration in markets.
  - Further develop, implement and test a method to reduce the number of scenarios considered in stochastic programming when implemented with a rolling time horizon.
  - Solve multiple variations of a bi-level optimization problem with uncertainty in the lower-level market equilibrium sub-problem.

Method and Deliverables

- **Methods:** Scenario reduction in stochastic programming using a rolling time horizon.
- **Achieved**: Demonstration of scenario reduction method for generation expansion in a small system. Solution of at least two versions of the bi-level optimization model.
- **Final**: Comprehensive test of new scenario reduction heuristic against other methods in realistic-sized generation expansion problems. Full case study of bi-level optimization on a realistic system to demonstrate scalability.

TA5.2 Hierarchical Probabilistic Coordination and Optimization of DERs and Smart Appliances

- Task Leader: A. P. Meliopoulos, Georgia Tech
- Problem to be Addressed
  - Need to integrate smart grid technologies, renewables, smart appliances, PHEVs, etc. into an optimized system of systems that can mitigate the effects of uncertainties.
- Quantification of:
  a) Resulting savings,
  b) Impact on GHG emissions
  c) Shifts in primary fuel utilization.



System Optimization

Short Term Forecasting

Targets for Substation
(Totals for Substation by Stage)
- Stored Energy
- Deferred Loads,
- Reactive Power, etc.

Aggregate Substation Model
(Totals and Limits for Substation by Stage)
- Stored Energy
- Deferred Loads,
- Reactive Power, etc.

Substation Optimization

Short Term Forecasting

Target Totals for Feeder
(Totals for Feeder by Stage)
- Stored Energy
- Deferred Loads,
- Reactive Power, etc.

Aggregate Feeder Model,
(Totals and Limits for Feeder by Stage)
- Stored Energy
- Deferred Loads,
- Reactive Power, etc.

Feeder Optimization

Short Term Forecasting

Method and Deliverables

- **Methods:** Hierarchical stochastic optimization and control
- **Achieved:** Simulation results for a typical system that quantifies the savings in fuel costs, shifting of primary fuel utilization, and reduction in greenhouse emissions.
- **Final:** A hierarchical optimization model and results from case studies.

TA5.3 Real-Time PMU-Based Tools for Monitoring Operational Reliability

- Task Leader: Alejandro D. Dominguez-Garcia, University of Illinois
  Collaborators: Peter W. Sauer, University of Illinois

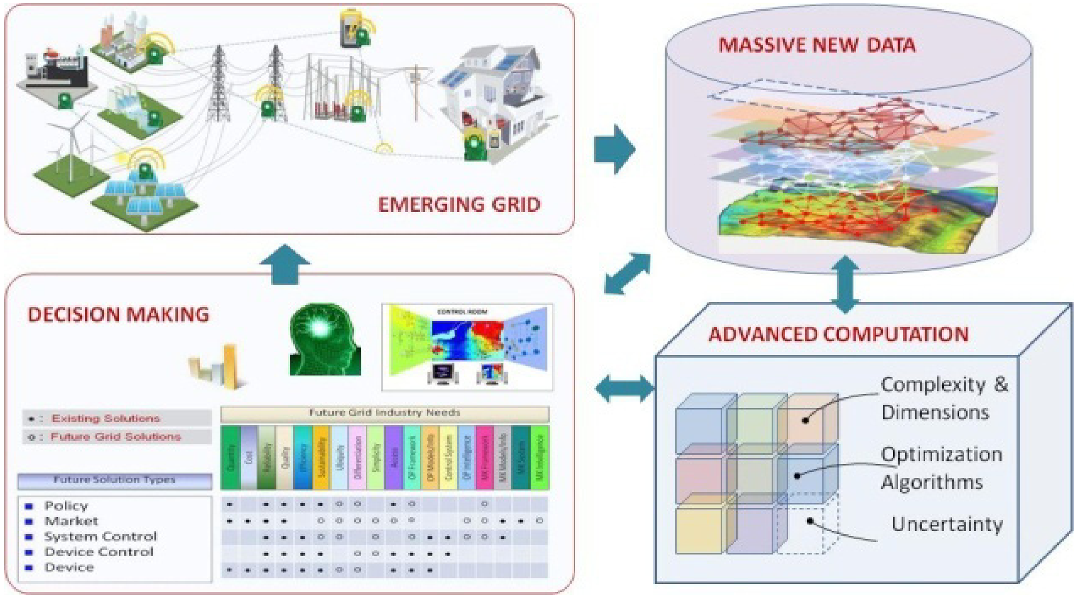
- Specific Problem to be Addressed
  - Need for real-time PMU-based tools for helping operators with operational reliability issues:
    1. System loadability monitoring,
    2. Transient stability analysis, and
    3. Real-time line model and equivalent parameter updating.
  - Develop recursive-filtering techniques for appropriately handling of phasor measurement data and estimating the parameters of interest.

Method and Deliverables

- **Methods:** Prob. 1 & 2: PMU data alone without assuming any knowledge of the system topology. Prob. 3: Individual transmission model.
- **Achieved:** PMU data filtering algorithms and theory of model-less loadability monitoring.
- **Year 2:** Line model and equivalent updating algorithms based on PMU data.
- **Final:** Feasibility of performing transient stability using PMU measurements on certain monitored lines.

TA5.4 Decision-Making Framework for the Future Grid

- Task Leader: Santiago Grijalva, Georgia Tech
- Specific Problem to be Addressed
  - Characterize emerging decision processes at new spatial and temporal scales.
  - Identify new decision makers and address decision complexity.
  - Identify gaps and technological needs for effective decision-making.



■ : Existing Solutions

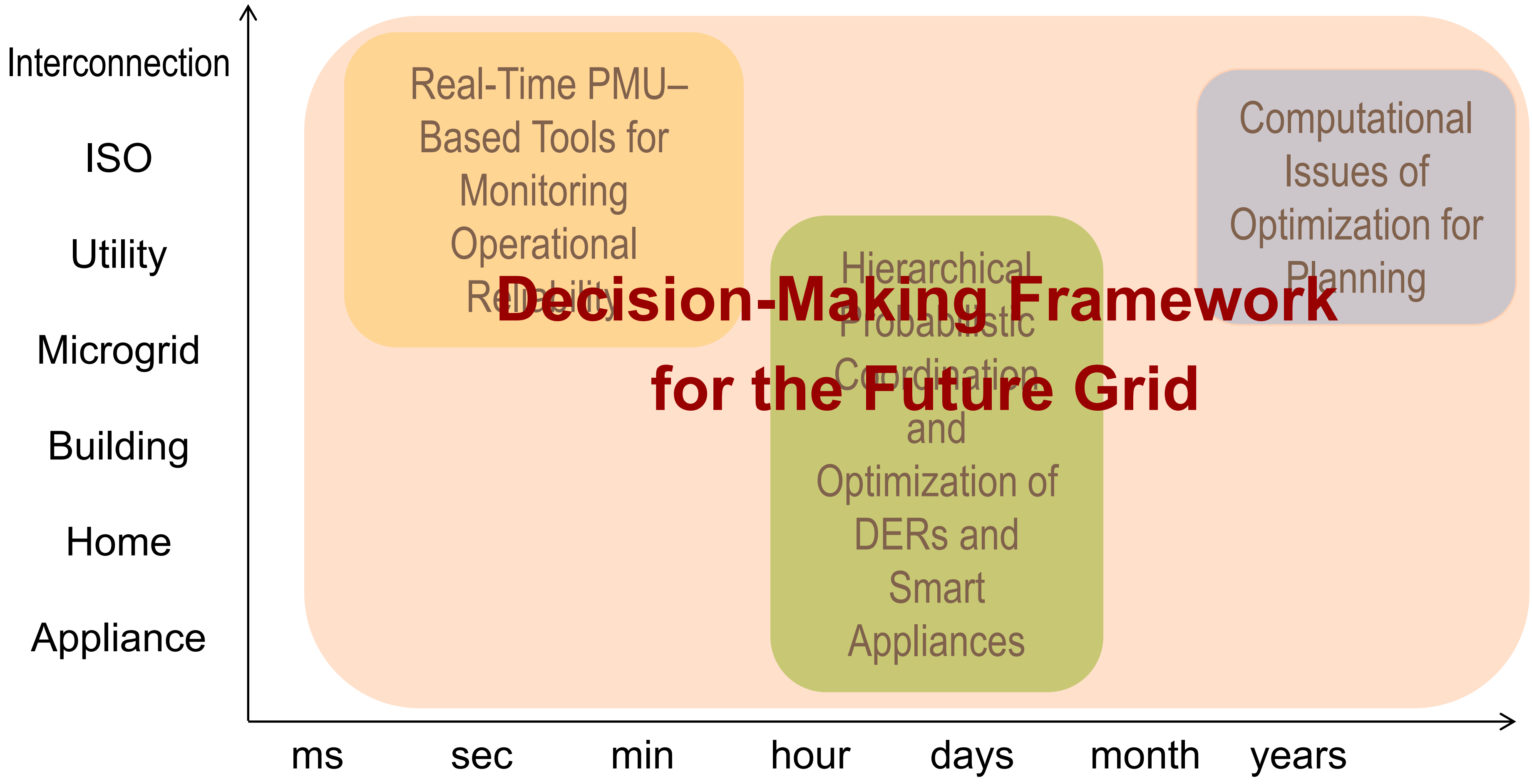
○ : Future Grid Solutions

	Future Grid Industry Needs																	
Future Solution Types	Quantity	Cost	Reliability	Quality	Efficiency	Sustainability	Ubiquity	Differentiation	Simplicity	Access	OP Framework	OP Models/Info	Control System	OP Intelligence	MK Framework	MK Models/Info	MK System	MK Intelligence
Policy	■		■	■	■	■	○	○		■	○				○			
Market	■	■	■	■		○	○	○	○	○	○			○	○	■	■	○
System Control			■	■	■	○	○		○		○	■	■	○	○	■		
Device Control			■	■	■	■		○	○	■	■	■	■					
Device	■	■	■	■	■	■	○	○		■	■	■						

Method and Deliverables

- **Methods:** Complex systems, formal informatics mapping methods, information flow, agent-based simulations, gap analysis.
- **Achieved:** Categorized list of new decisions, data requirements, and layered architecture.
- **Y2:** Data, computation, and analytical gaps.
- **Final:** Critical decision points and processes.
- Automated, machine-learned and human decisions.
- Massive data and computation module interfaces.
- Demonstration for 3 areas: transmission investment, restoration, and consumer management.

TA5 Summary



Interconnection

ISO

Utility

Microgrid

Building

Home

Appliance

Real-Time PMU–Based Tools for Monitoring Operational Reliability

Hierarchical Probabilistic Coordination and Optimization of DERs and Smart Appliances

Computational Issues of Optimization for Planning

Decision-Making Framework for the Future Grid

ms sec min hour days month years

Conclusions

- Research Priorities
  - Enhanced stochastic optimization algorithms
  - Distributed computational framework under a cyber-physicals systems (CPS) formalism.
  - Distributed power system control algorithms
  - Access to realistic test data
  - Availability to benchmark software