The Future Grid to Enable Sustainable Energy Systems

PSERC's Future Grid Initiative

Supported by DOE

PSERC IAB Meeting
May 11-13, 2011

Overview

Vijay Vittal
PSERC Director
Arizona State University

Background

- In 2009 March during the EC Retreat PSERC, put out two white papers which addressed the topics of renewable integration and topics related to grid evolution in a smart grid environment.
- These two white papers were widely disseminated.
- These papers caught the attention of the DOE Office of Electricity Delivery and Energy Reliability staff.

Background

- PSERC was approached to develop a comprehensive proposal addressing issues related to the future grid architecture, renewable resource integration, cyber-physical system interaction and workforce development.
- A detailed discussion was held at the 2010 summer workshop in Maine.
- A formal process for developing the main ideas and the proposal was formulated.

Background

- Six thrust areas were identified.
- A large selection of topic ideas raised at the workshop and submitted via a general request to PSERC industry members and researchers were categorized by the thrust area leaders.
- A complete draft of topics were sent to DOE, the Executive Committee, and the IAB for comments.
- The director consolidated the feedback.

Background

- Then all researchers received an “Invitation to Submit Ideas for Research and Education, and for Broad Analysis on The Future Grid to Enable Sustainable Energy Systems”.
- Submittals were reviewed by the thrust area leaders and the director.
- Investigators identified by that review were invited to write detailed descriptions for tasks in each thrust area.
- More tasks were identified than there were funds to support.

Background

- A draft proposal was prepared.
- It was reviewed by three anonymous academic reviewers and two IAB members.
- Based on this review, with consideration of the budget, a final set of tasks in each thrust area was determined by the thrust area leaders and the director.
- The final proposal was prepared submitted to DOE. After a review DOE responded with a few clarifications and approved the proposal.

Background

- The proposal was approved in Dec 2010.
- Funds reached each university in early February 2011 via supplements to the NSF IUCRC grants.
- Work has commenced on the project.

Thrust Areas

- Electric Energy Challenges of the Future
- Control and Protection Paradigms of the Future
- Renewable Energy Integration and the Impact of Carbon Regulation on the Electric Grid
- Computational Challenges and Analysis Under Increasingly Dynamic and Uncertain Electric Power System Conditions
- Engineering Resilient Cyber-Physical Systems
- Workforce Development

Thrust Area Deliverables

- White papers describing thrust area research context, problem statements, methodology, and deliverables (March 1, 2012)
- Public review workshops (Dec. 7, 2011 and Fall 2012).
- The draft thrust area final reports are due in April 2013. After a public workshop, the final reports will be submitted to DOE in August 2013.

Broad Analysis Areas

- Topics
  - The Information Hierarchy for the Future Grid
  - Grid Enablers of Sustainable Energy Systems
- Deliverables
  - White papers (by January 1, 2012)
  - Workshops in each area (June of 2012)
  - Final reports with proceedings (August 2012)

Electric Energy Challenges of the Future

Jerry Heydt
Arizona State University

Context of this Area's Research

PSERC

- **Topical areas:** the integration of renewable resources into the system; the direct digital control of the system; the maximization of the use of sensory information to use the assets that we have.
- **Goals:** to use newly available information in mathematics and statistics, instrumentation and control, communications and computing, and advanced concepts of transmission engineering to achieve the objectives of renewable resource integration, maximal system operability and reliability, and making use of digital technology where it is warranted and human operator skills where they are needed.
- **Focus:** four critical areas: (1)Transmission system design, (2) Substantive changes in power distribution systems, (3) Dynamic balancing of load and generation, and (4) wide area controls.
- These basic elements are brought together by an integrative task which identifies the likely future technologies that need to be included in the analysis and research of the identified critical areas. The integrative task is intended to focus on the next thirty years.

Tasks

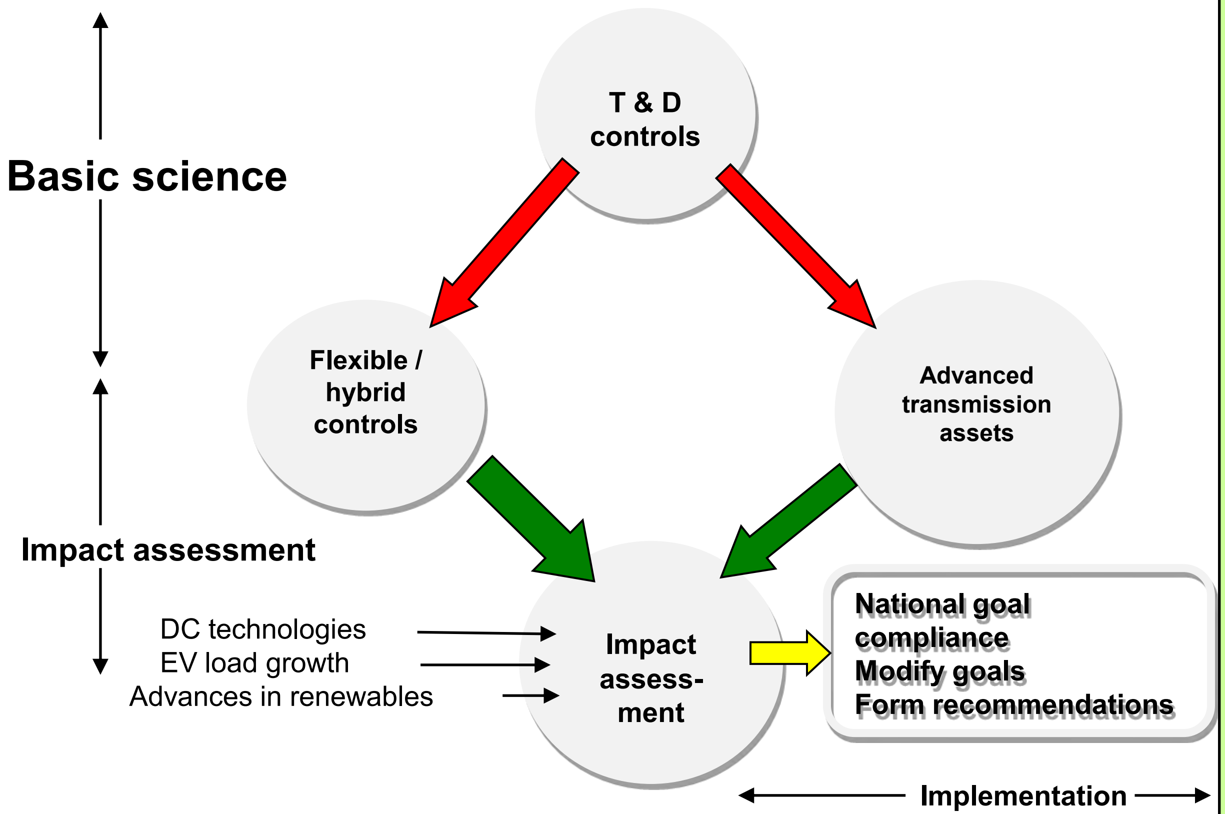
- Integrating Transmission and Distribution Engineering Eventualities
- A National Transmission Overlay
- Robust and Dynamic Reserve Requirements
- Wide Area Control Systems

Integrating Transmission and Distribution Engineering Eventualities

Task Leader: Jerry Heydt
Arizona State University

- An integrative research task
- To bring together research and analysis of several energy transmission and distribution eventualities
- Engineering and scientific breakthroughs and significant advances that are hardware oriented.
- The objective is to examine *'what if'* a given eventuality is implemented in the
- Projections of penetration levels of new technologies both at the transmission and distribution levels
- Both probabilistic and worst-case engineering analyses.

Specific Problems to be Addressed



- Implementation of UHV technologies
- Networked DC systems
- Synchronous interconnected system designs and limits
- Integration of transmission and distribution controls
- Implementation of multiobjective controls
- Hybrid controls / paralleling electronic controls and AC circuits
- Modification of operating practices
- Relaxing AGC operational limits
- Relaxing selected protection practices

Methods and Deliverables

PSERC

Sub-task	Objectives	Research methods
1 Breakthroughs in large scale transmission technologies	• Implementation of UHV technologies • Networked DC systems • Synchronous interconnected system designs and limits	• Access transmission experts to identify advanced transmission technologies • Study of sample systems with networked DC • Stability studies of large scale networks that are successively split along coherent regions
2 Advanced control methods	• Integration of transmission and distribution controls • Implementation of multiobjective controls • Hybrid controls / paralleling electronic controls and AC circuits	• Utilization of new electronic controls including hybrid controls in test beds • Development of multiobjective control test cases • Research on new ideas of distribution system controls – including signals from the transmission system
3 Flexible policies	• Modification of operating practices • Relaxing AGC operational limits • Relaxing selected protection practices	Testing relaxation and tightening of various operational limits, identifying the consequences, and evaluation of cost / benefit including consequences of outages and / or loss of power market revenues.
4 Breakthrough analysis	• Assessment of integrating several breakthroughs • Assessment of implementing technologies in Task 1 • Project documentation	Integration and documentation of results from this task, including the work of the other PIs indicated subsequent to this section

A National Transmission Overlay

Task Leader: Jim McCalley
Iowa State University

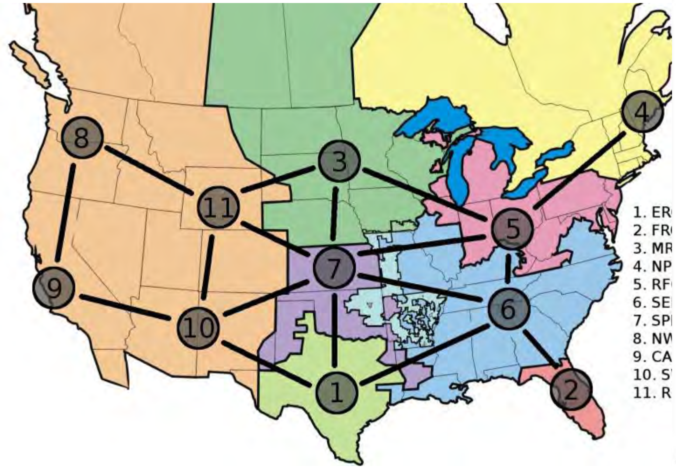
Collaborator: Dionysius Aliprantis
Iowa State University

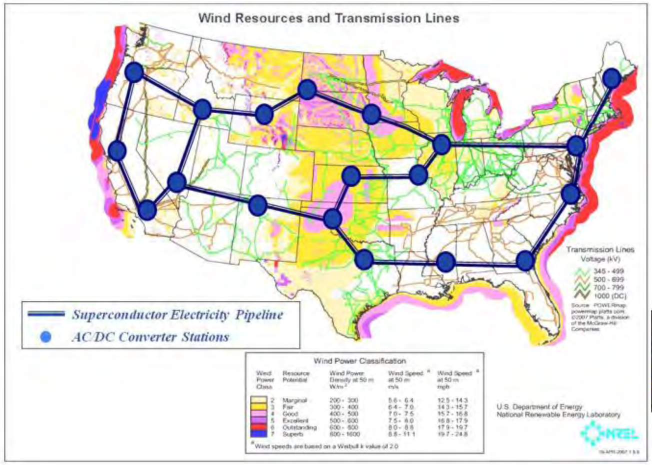
Specific Problem to be Addressed

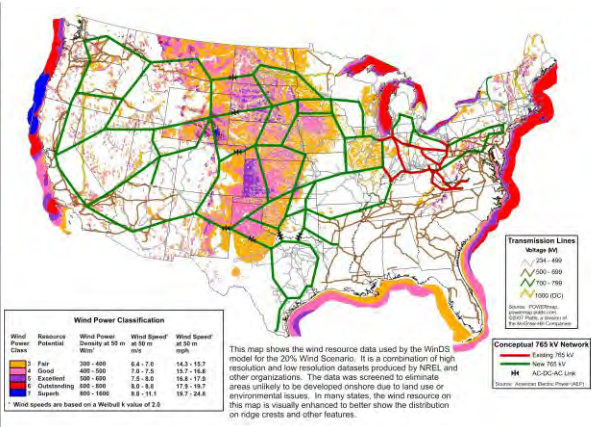
This project addresses the grand challenge of charting a 40 year investment path to bring US CO_2 emissions to acceptable levels while maintaining low cost energy and a resilient infrastructure.

Objectives:

- **Design US national transmission overlays**
- **Develop associated design process to facilitate growth of wind, solar, nuclear, geothermal, biomass, clean-coal, & natural gas generation to 2050.**
- **Assess value of each overlay design**







Method and Deliverables

1. Model development (yr 1): Already developed national energy system data representing electric, natural gas, rail system, loading of passenger and commodity transportation on energy system, w/ planning software NETPLAN. Will increase granularity of existing transmission representation.

2. Futures (yr 1): Design 7 "futures" in terms of load growth and generation investment: reference, high wind, high solar, high geo-thermal, high nuclear, high clean-coal, and high natural gas.

3. Transmission technologies (yr 2): Develop cost, efficiency, and reliability data for all viable transmission technologies, including HVAC overhead (500 kV, 765 kV), HVDC overhead (600 kV, 800 kV), HVDC under-ground.

4. Optimization (yr 2): Use NETPLAN to identify the effective (in terms of cost, resiliency, and emissions) transmission plan for each future.

5. Production costing (yr 2): Perform 8760 hour production cost studies for year 2050 to identify impact on social welfare of each transmission plan.

6. Robust testing (yr 3): Evaluate each plan for the remaining six futures, to determine which plan is most robust to future uncertainties.

Deliverables: Planning software, a design process, summary of recommended transmission overlay designs/values for each future.

Method and Deliverables

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Robust and Dynamic Reserve Requirements

Task Leader: Kory W. Hedman
Arizona State University

- Reserve requirements
  - Integral to maintaining a reliable system
  - **Surrogate method,** as opposed to explicit representation of contingencies, N-1
    - Does not account for actual power flow during the contingency
  - Ad-hoc, rule-of-thumb methods to determine reserve levels and reserve zones
  - **Need for improved mathematical models to determine optimal reserve requirements**
    - Updates needed to accommodate intermittent resources

Specific Problem to be Addressed

- Current practices
  - CAISO operating reserve level:
  - Max(OR1, OR2) + 100% Non-firm Imports
  - OR1: 5% hydro scheduled, 7% non-hydro
  - OR2: MW lost due to single worst contingency
  - Applies to each reserve zone
- How to determine the zones?
- How to determine the reserve level?
  - Historical information?
  - Stochastic optimization?
- How to update reserve requirements for:
  - Intermittent resources (wind, solar)?
  - Development of a smart, flexible grid (SPSs, FACTS, switching)?

Method and Deliverables

- Current focus: How to determine reserve zones?
  - Network partitioning
    - Mathematical extension to islanding models?
  - Generator clustering
    - Define a zone as a cluster of generators with a specific reserve requirements *(instead of a network partition)*
    - Clusters need not be separable, may overlap
    - Generators may belong to more than one cluster
    - **Ability to replicate "Interruptible Imports" and RMR units**
    - Deliverable: Mathematical formulation to determine optimal generator clusters to supply reserve
- Reserve level, intermittent resources:
  - Stochastic optimization
  - Scenario selection

Wide Area Control Systems

Task Leader: Mani Venkatasubramanian
Washington State University

- Wide-area control techniques for future power system with large portion of renewable power generation and abundance of PMUs
- Algorithms for voltage stability, oscillatory stability and angle stability controls – formulation and test results on test cases

Specific Problem to be Addressed

- Future wide-area controls:
  - Assume abundance of PMUs
  - Assume suitable communication network
  - What types of new wide area controls?
  - Coordinated voltage controls
  - Real-time wide-area oscillatory controls
  - Angle stability controls

Method and Deliverables

- Voltage controllers: substation designs and coordinated wide-area designs in medium-scale power system (1st year)
- Oscillatory stability controllers: wide-area designs using real-time modal analysis (2nd year)
- Angle stability controls: formulation and preliminary test results (3rd year)

Control and Protection Paradigms of the Future

Anjan Bose
Washington State University

Context of this Area’s Research

- New technologies make feasible wide area control and protection (as opposed to only local)
- One-of-a-kind wide area control/protection have been used but are expensive
- A framework is needed for the design and deployment of such control/protection:
  - Hierarchical and Coordinated
  - Communication/computation infrastructure

Tasks

- Requirements for Hierarchical Coordinated Control and Protection of the Smart Grid
- Hierarchical Coordinated Control of Wind Energy Resources and Storage for Electromechanical Stability Enhancement of the Grid
- Hierarchical Coordinated Protection of the Smart Grid with High Penetration of Renewable Resources

Requirements for Hierarchical Coordinated Control and Protection of the Smart Grid

Task Leader: Anjan Bose
Washington State University

Specific Problem to be Addressed

- **The main objective** is to define the overall concept for hierarchical coordinated control and protection of the smart grid.
- **The methodology** is the time simulation of communication and computation infrastructure that is compatible with the time simulation of the power grid.

Method and Deliverables

- **First Year Deliverables:**
  - Communication and computation models/simulation
  - White paper describing the framework
- **Final Deliverables:**
  - Simulation to simulate the integrated IT infrastructure and the power grid
  - Test results from simulations
  - Final report

Hierarchical Coordinated Control of Wind Energy Resources and Storage for Electromechanical Stability Enhancement of the Grid

Task Leader: Chris DeMarco
Univ. of Wisconsin-Madison

Collaborators: Bernard Lesieutre and Yehui Han, Univ. of Wisconsin-Madison

Specific Problem to be Addressed

- This project will develop control methodologies and designs that optimally mix nonsynchronous, variable generation sources such as wind and photovoltaic, with electrical energy storage resources, such as batteries, supercapacitors, and flywheels.
- It will address the problem of maintaining grid electromechanical stability as the percentage of power production from synchronous generators, the traditional grid stabilizing mechanism, decreases in the coming decade.

Method and Deliverables

- **First Year Deliverables:**
  - Proof-of-concept of controller design for wind turbines energy storage.
  - White paper on the controller framework.
- **Final Deliverables:**
  - Specific controller designs for coordinated MIMO control of wind farms and grid-scale battery storage.
  - Testing these control designs for enhancing stability in commercial package like PSSE.

Hierarchical Coordinated Protection of the Smart Grid with High Penetration of Renewable Resources

Task Leader: Mladen Kezunovic
Texas A&M University

Specific Problem to be Addressed

- The objective is to define the three hierarchical coordinated layers:
  - Predictive protection
  - Inherently adaptive protection
  - Corrective protection
- The methodology will be to use real life system scenarios to demonstrate some of the findings. Modeling and simulation will also be used extensively.

Method and Deliverables

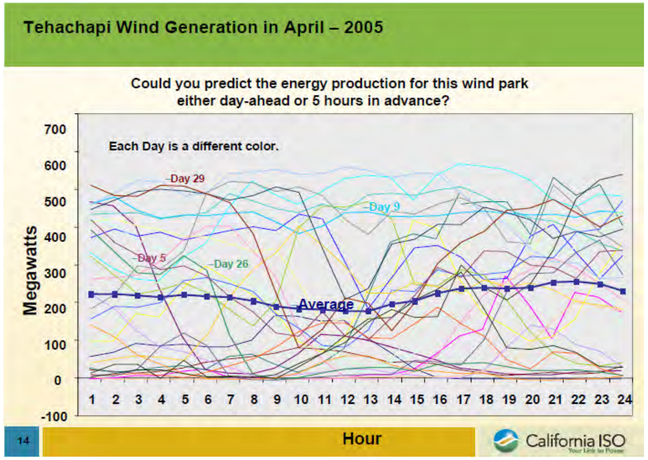
- **First Year Deliverables:**
  - Development of overall hierarchical coordination scheme with initial details of the protection layers and coordination between layers.
  - White paper describing the framework for hierarchical coordinated protection.
- **Final Year Deliverables:**
  - Report with the full details of the new concept and experimental results will be prepared.

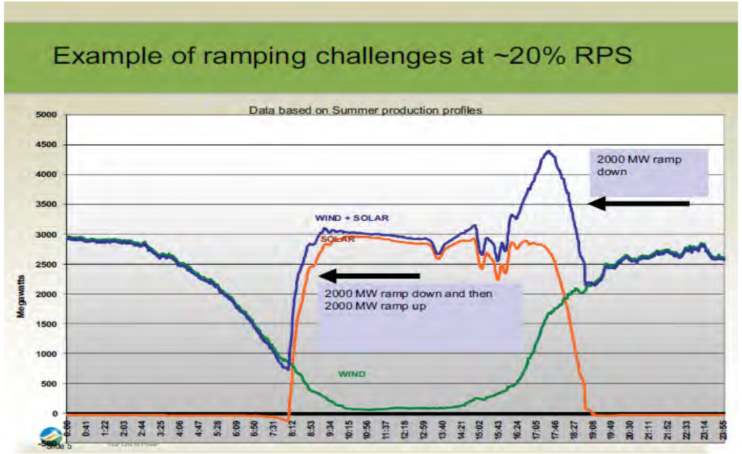
Renewable Energy Integration and the Impact of Carbon Regulation on the Electric Grid

Shmuel Oren
University of California
at Berkeley

Context of this Area's Research

- High penetration levels of intermittent renewable resources pose operational challenges due to their high variability and uncertainty even at short time scales





- Providing sufficient operating reserves on the supply side is unsustainable from a resource mix perspective and it undermines the economic and environmental benefits of renewable resources.
- Key solution concepts:
  - **Exploit load flexibility (thermostatically controlled loads, agricultural pumping, EV/PHEV charging,) through direct and indirect (price response) load control**
  - **Paradigm shift from generation following load to load following available supply**

Tasks

- Direct and Telemetric Coupling of Renewable Energy Resources with Flexible Loads
- Mitigating Renewables Intermittency Through Non-Disruptive Distributed Load Control
- Planning and Market Design for Using Dispatchable Loads to Meet Renewable Portfolio Standards and Emissions Reduction Targets
- Probabilistic Simulation Methodology for Evaluating the Impact of Renewables Intermittency on Operation and Planning

Direct and Telemetric Coupling of Renewable Energy Resources with Flexible Loads

Task Leader: Shmuel Oren
University of California at Berkeley

Specific Problem to be Addressed

- Alternative approaches to renewables integration:
  - Feed available renewable energy into market and adjust dispatch, prices and reserves to account for uncertainty and volatility – direct load control and price responsive demand can be used to supply increased reserves needs, ramp capability and balancing energy.
  - Direct or telemetric coupling of flexible demand with renewable energy so that load fully or partially follows available renewable supply and bears availability risk (dynamic scheduling)
- Challenges:
  - Design distributed controls that will combine renewable energy and spot energy to serve flexible loads at least cost (e.g. smart EV/PHEV charging)
  - Develop dispatch models that explicitly account for resource and load uncertainty to assess the relative economic and performance outcomes of market based renewable integration vs. direct coupling

Method and Deliverables

- Wind generation and load characterized using stochastic dynamic models calibrated to NREL and CAISO data.
- Two stage stochastic unit commitment algorithms used for dispatch and reserves commitment decisions.
- Monte Carlo simulation model for testing the performance of dispatch algorithms and renewable integration approach
- Deliverables:
  - New multi area, scenario driven, stochastic unit commitment method with endogenous reserves determination
  - Performance evaluation of, endogenously determined vs. preset levels of reserves, in system with high renewable penetration levels
  - Economic and performance evaluation of direct coupling approach

Mitigating Renewables Intermittency Through Non-disruptive Distributed Load Control

Task Leader: Duncan Callaway
University of California at Berkeley

Specific Problem to be Addressed

- Renewable electricity sources are variable, difficult to forecast
- Distributed energy resources (including storage and controllable load) can mitigate
- Challenges lie in:
  - Modeling aggregations of resources in tractable, meaningful ways
  - Coordinating control signals that balance system level objectives with local resource objectives

Method and Deliverables

- State space models and control of load aggregations
  - quantify communication requirements for controllability, observability, etc
  - constrained optimal control
- Deliverables
  - First year: Large-scale modeling and state estimation strategies for demand response.
  - Final: Evaluating the technical and economic impacts of demand response for renewables integration

Planning and Market Design for Using Dispatchable Loads to Meet Renewable Portfolio Standards and Emissions Reduction Targets

Task Leader: Tim Mount
Cornell University

Collaborators: K. Max Zhang
and Robert J. Thomas
Cornell University

Specific Problem to be Addressed

- Identify the needs for different types of power system services
- Examine the engineering/economic feasibility of aggregating dispatchable loads to provide system services
- Evaluate the performance of a unified market for multi-timescale power system services

Method and Deliverables

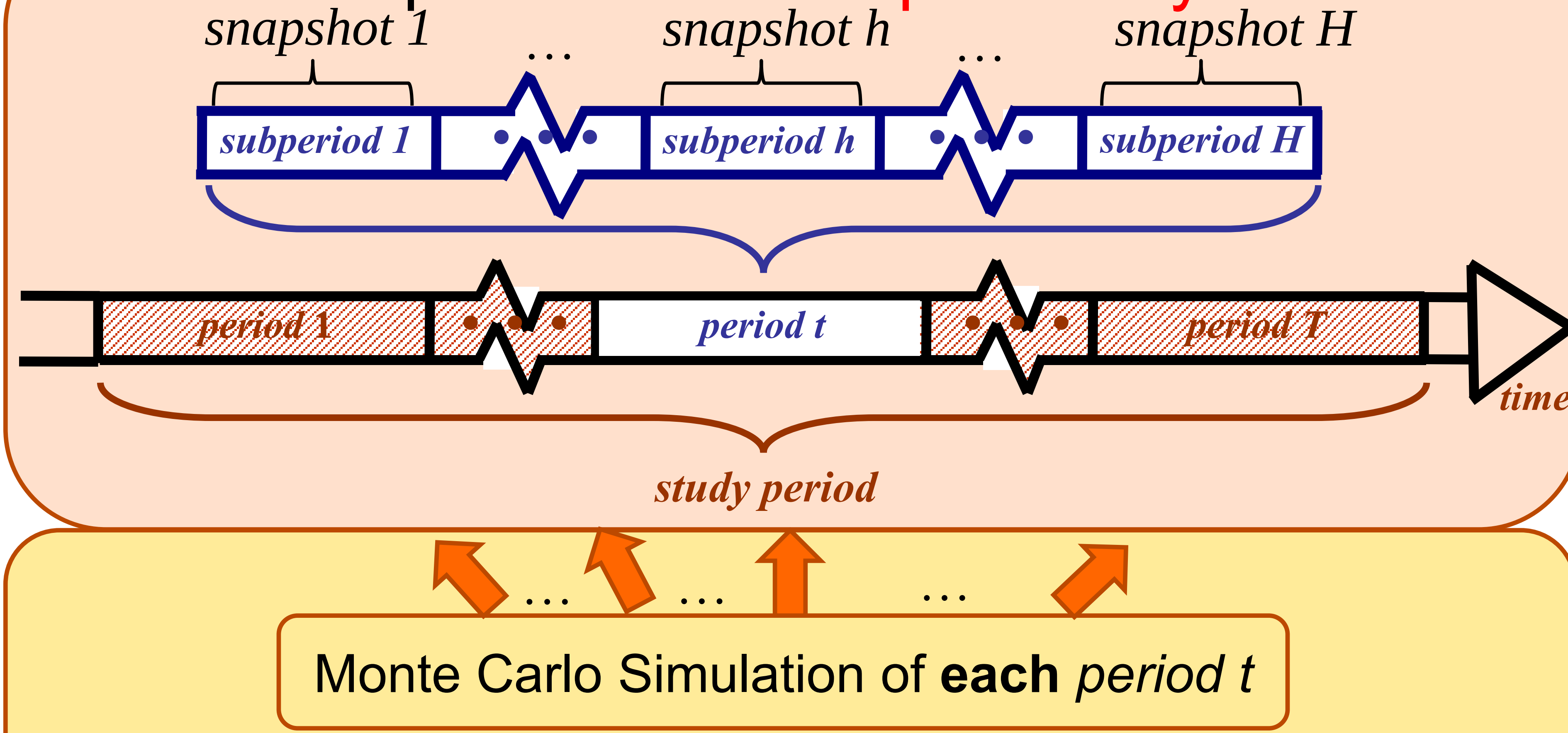
- Method
  - Develop an integrated environmental/power systems analysis using a reduction of the NPCC network
  - Develop engineering models for intelligent EV charging and controllable HVAC systems
  - Compute power system simulations for different renewable penetration levels and market designs
- Deliverables
  - A matrix listing the requirements for different types of system services in the Northeast region
  - New market products for incorporating dispatchable loads
  - Evaluation and recommendations on how to improve current market designs and environmental quality

Probabilistic Simulation Methodology for Evaluating the Impact of Renewables Intermittency on Operation and Planning

Task Leader: George Gross
University of Illinois at Urbana/Champaign
Collaborator: Alejandro Dominguez-Garcia
University of Illinois at Urbana/Champaign

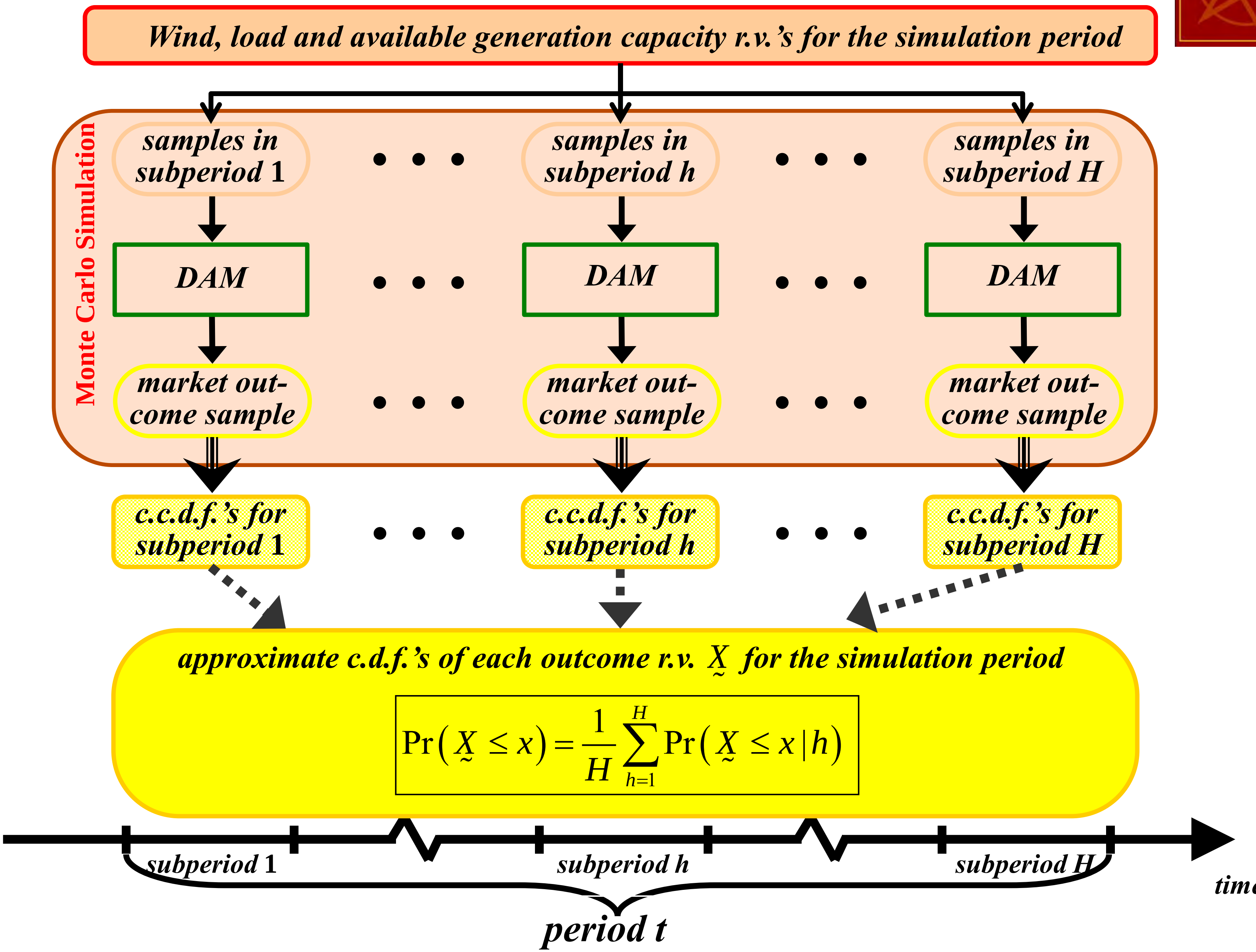
Specific Problem: Capture of both Time-Dependency and Uncertainty

- Capture of time-dependency…



- … and uncertainty.

Method and Deliverable



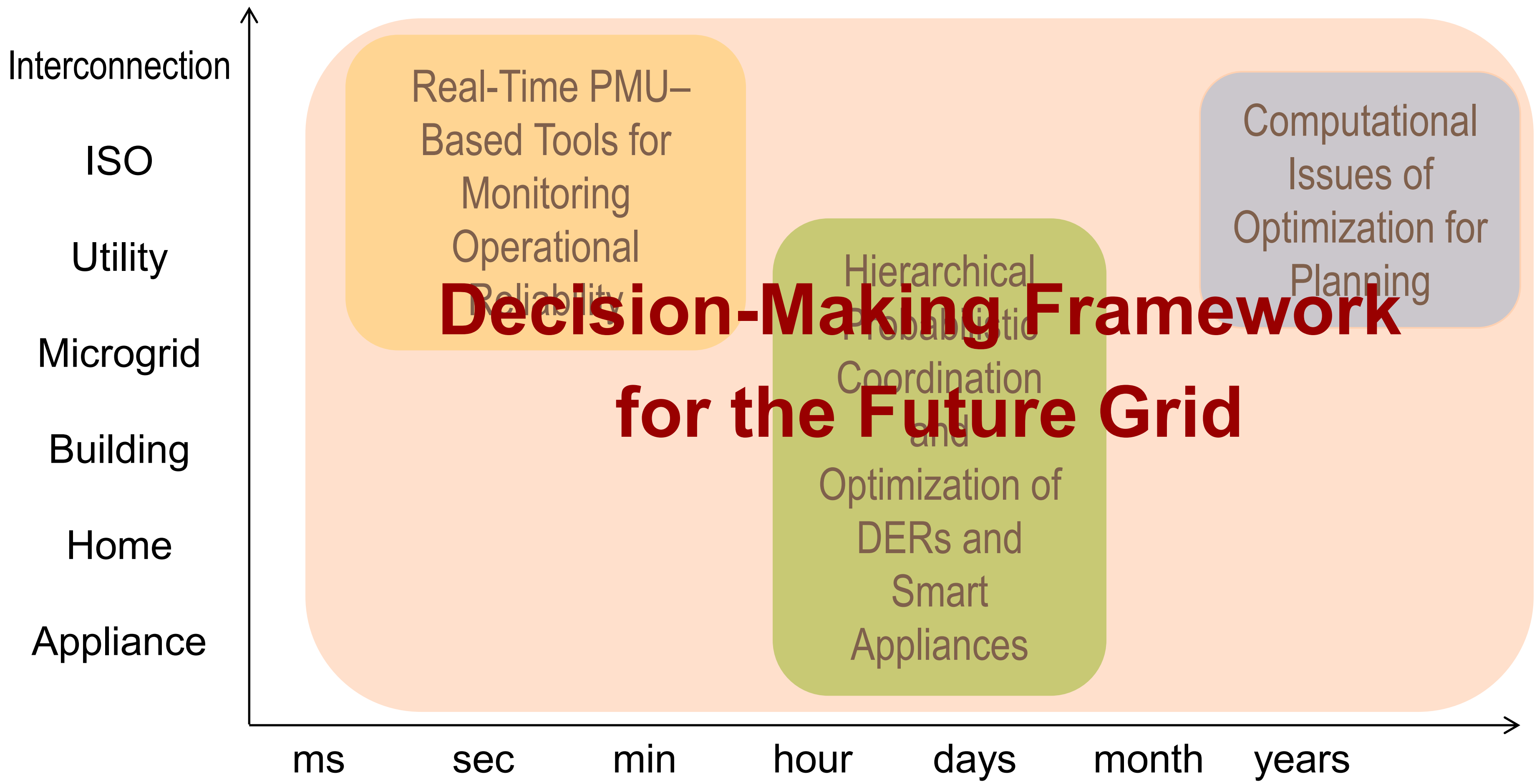
Computational Challenges and Analysis Under Increasingly Dynamic and Uncertain Electric Power System Conditions

Santiago Grijvalva
Georgia Institute of Technology

Context of this Area's Research

- Sustainability objectives coupled to more ambitious grid economy and reliability goals results in difficult computational problems:
  - Existing tools exhibit fundamental limitations.
  - New decision-making must account for uncertainty and computational systems must be much more powerful.
- PMU, AMI, and IED's data provides great opportunities for improved processes:
  - Ways must be found to aggregate, organize, and secure data so it can be leveraged.

Tasks


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

Computational Issues of Optimization for Planning

Task Leader: Sarah M. Ryan
Iowa State University

Specific Problem to be Addressed

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- 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.

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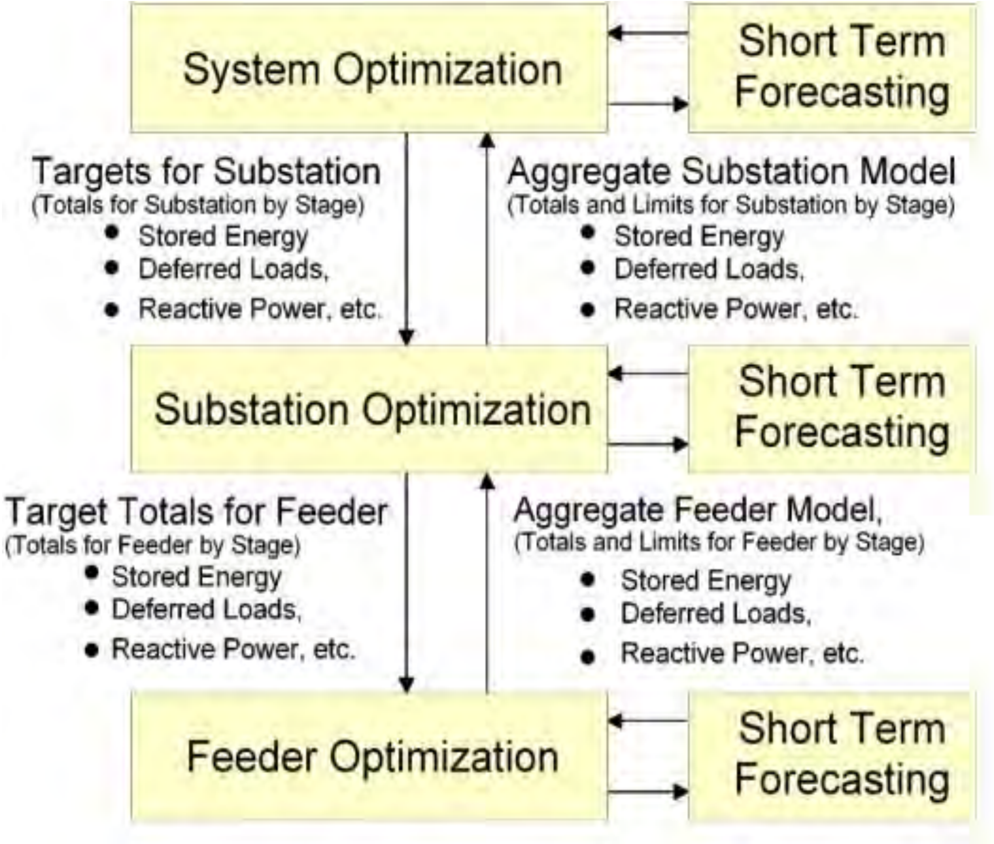
Method and Deliverables

- **Methods:** Scenario reduction in stochastic programming using a rolling time horizon.
- **Year 1**: 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.

Hierarchical Probabilistic Coordination and Optimization of DERs and Smart Appliances

Task Leader:
A. P. Meliopoulos
Georgia Institute of Technology



Specific 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) The resulting savings,
  b) The impact on GHG emissions
  c) The shifts in primary fuel utilization.

Method and Deliverables

- **Methods:** Hierarchical stochastic optimization and control
- **Year 1:** Simulation results for a typical system that will quantify the savings in fuel costs, shifting of primary fuel utilization, reduction in greenhouse emissions and other attributes from the proposed hierarchical optimization approach.
- **Final:** A hierarchical optimization model and results from case studies.

Real-Time PMU-Based Tools for Monitoring Operational Reliability

Task Leader: Alejandro D. Dominguez-Garcia
University of Illinois at Urbana-Champaign

Collaborator: Peter W. Sauer
University of Illinois at Urbana-Champaign

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.

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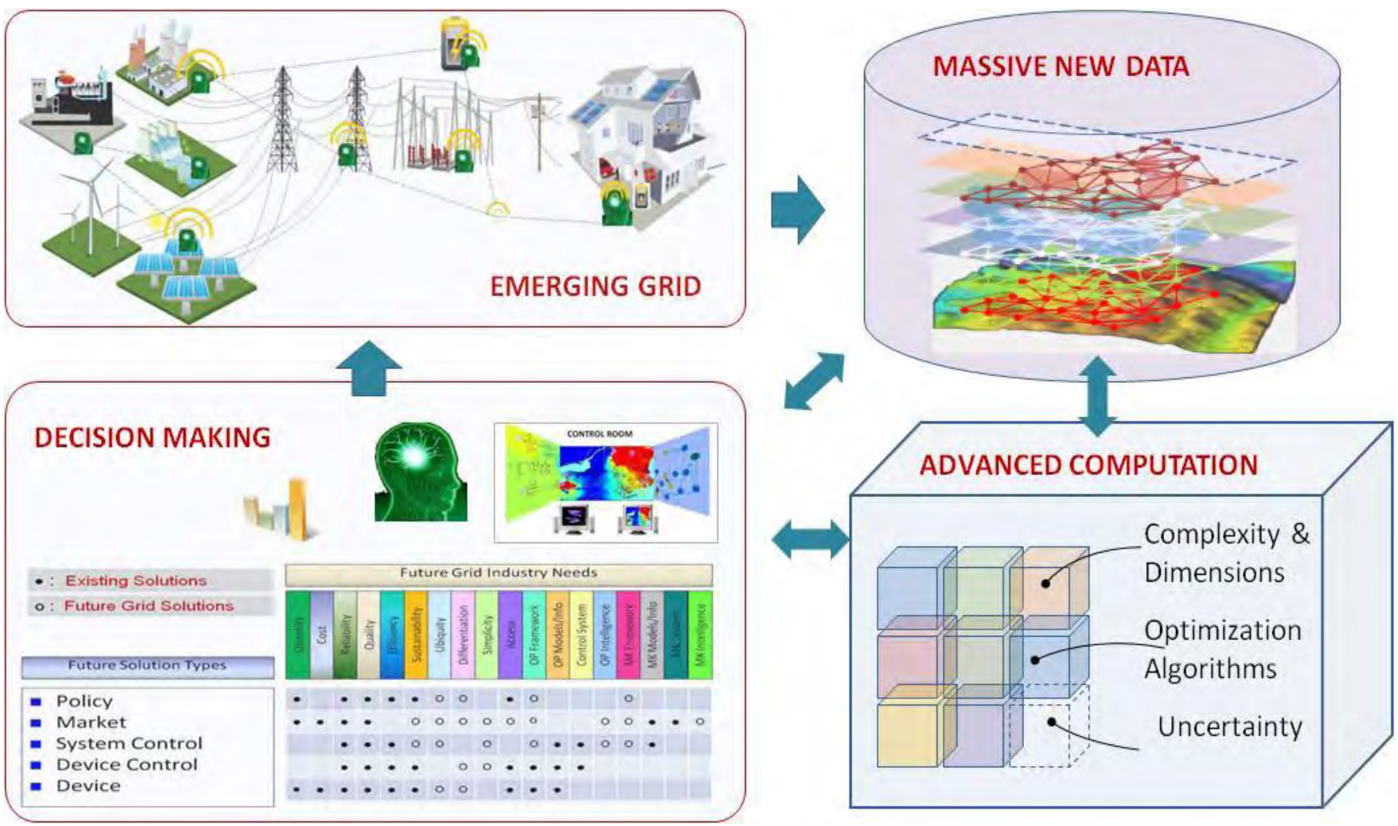
Method and Deliverables

- **Methods:** Prob. 1 & 2: PMU data alone without assuming any knowledge of the system topology. Prob. 3: Individual transmission model.
- **Year 1:** 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.

Decision-Making Framework for the Future Grid

Task Leader: Santiago Grijalva
Georgia Institute of Technology



Specific Problem to be Addressed

- Understand emerging decision-making processes at new spatial and temporal scales.
  - New ecosystems and decision makers
- Address decision complexity.
- Identify gaps and technological needs for effective decision-making across the industry.
- Ensure that the objectives of the future grid are met.

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Method and Deliverables

- **Methods:** Complex systems, formal informatics mapping methods, information flow, agent-based simulations, gap analysis.
- **Year 1:** Categorized list of new decisions, data requirements, and layered architecture.
- 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.

Engineering Resilient Cyber-Physical Systems

Tom Overbye
University of Illinois
at Urbana/Champaign

Tasks

- Resiliency With Respect to Low Frequency, High Consequence Events
- Operational and Planning Considerations for Resiliency
- Improved Power Grid Resiliency through Interactive System Control

Resiliency with Respect to Low Frequency, High Consequence Events

Task Leader: Tom Overbye
University of Illinois at Urbana/Champaign

Specific Problem to be Addressed

- Game Changing Power System Scenarios, such as a strong geomagnetic storm that could disable 100's of transformers
  - Power system analysis techniques for game changing scenarios
  - Improved situational awareness for extreme system operation
  - Data mining applications to quickly learn operational issues during extreme system operating conditions

Method and Deliverables

- Will be concentrating on power flow and transient stability time frames, with emphasis on algorithm robustness
- As much as possible techniques will be applied to actual power system models
- Results will be delivered using the standard techniques of papers, a website, and reports; case study examples will also be made available

Operational and Planning Considerations for Resiliency

Task Leader: Ian Dobson
University of Wisconsin-Madison

Specific Problem to be Addressed

- Overall objective is to engineer power transmission system resilience to minimize the risk of cascading failure blackouts
- To address this problem the concept of power grid resilience needs to be quantified.

Method and Deliverables

- Develop case studies to quantify blackout risk using observed power system data
- Develop case studies for quantifying and mitigating blackout risk using simulated power system data
- Develop methods for communicating risk results to policy makers and engineers.
- Results will be delivered using the standard techniques of papers, a website, and reports; also case study examples

Improved Power Grid Resiliency through Interactive System Control

Task Leader: Vijay Vittal
Arizona State University

Specific Problem to be Addressed

- Problem is that with an increased penetration of less certain renewable generation resources, control and its communication will become more important
- Research focuses on using interactive system control to improve grid resiliency.
- The use of synchronized measurements will be crucial

Method and Deliverables

- Identify the synchronized area measurements that would enable decision making and corrective control
- Design controls that incorporate location based hierarchical signals to enhance system reliability and robustness
- Numerically test approaches using realistic power system models
- Reporting and dissemination through standard mechanisms

Workforce Development

Chanan Singh
Texas A&M University

Context of the Education Development Work

Future Grid:

- Heavy penetration of variable energy sources, central and distributed energy storage and massive deployment of distributed communication and computational technologies.
- Higher uncertainty in the planning and operation.
- The objective of this thrust is development of educational tools to meet the needs of the current and future engineers managing these complex cyber-physical systems as well as innovators to bring future transformations.
- It is the workforce that will produce innovative ideas and transformative changes needed to orchestrate a clean and sustainable energy smart grid.
- *The relevant education of this workforce is thus critical to the success of the future grid.*
- Topics included are generally not covered adequately in traditional curriculum.

Education Tasks

- Comprehensive Educational Tools for Reliability Modeling and Evaluation of the Emerging Smart Grid
- PSERC Academy: A Virtual Library of Thousands of Short Videos
- Smart Grid Education for Students and Professionals
- Energy Processing for Smart Grid Technology
- A Course in Energy Economics and Policy
- Course Development - “Critical Infrastructure Security: The Emerging Smart Grid”

Comprehensive Educational Tools for Reliability Modeling and Evaluation of the Emerging Smart Grid

Task Leader: Chanan Singh
Texas A&M University

Audience and Objective

- Educate current and future energy professionals in a systematic way of thinking, modeling, analyzing and predicting reliability.
- Educate energy industry professionals in modeling uncertainty through probabilistic modeling
- Provide hands on experience on the use of these tools through assignments and projects
- Stimulate more research and development in this field
- The target audience: students in the universities, working engineers and other professionals in the energy industry interested to develop expertise in this subject.

Deliverables

- Two sets of power points with notes will be developed:
  - one for a university based full semester course
  - the other for an internet based short course.
  - projects for both courses

PSERC Academy: A Virtual Library of Thousands of Short Videos

Task Leader: Raja Ayyanar
Arizona State University

Audience and Objective

- Objective : to develop an *online library* of short videos on various topics of sustainable energy systems, smart grid and power engineering, and on background topics required to understand these concepts.
- The vision: over a period of 3-5 years, develop hundreds of such videos covering a wide spectrum ranging from basic introductory material to advanced topics, delivered using a range of methods from simple lectures to sophisticated multi-media delivery.
- The target audiences: university students in power engineering or related disciplines, and practicing engineers.

Deliverables

- 200-300 short videos for modules on sustainable energy systems
- Report on the complete results of continuous quality assessments and impact analysis
- Proposal for sustaining the Academy after the project duration.

Smart Grid Education for Students and Professionals

Task Leader: Mladen Kezunovic
Texas A&M University

Collaborators: Sakis Meliopoulos, Georgia Institute of Technology
Vijay Vittal, Arizona State University
Mani Venkatasubramanian, Washington State University

Alex Sprintson, Texas A&M University

Audience and Objectives

- Develop comprehensive educational package that will reach out to educators, students, practicing engineers, managers, legislators, public officials, etc.
- Write a text book and prepare a set of supplemental PP presentations.
- The target audience: practicing engineers, students, managers, and non-technical persons need to master these new technologies in a way that corresponds to their role in the overall process of making such technologies a reality.

Deliverables

- Final version of the book
- Complete course package, including lecture nodes and sets of PP slides.

Energy Processing for Smart Grid Technology

Task Leader: James A. Momoh
Howard University

Collaborator: Peter A. Bofah
Howard University

Audience and Objective

- Enhancing power modules in the university in two major broad topics critical to the Nation's objective of attaining energy independence.
  - smart grid fundamentals and applications;
  - integration of renewable energy resources into the bulk power system.
- Integration of laboratory work in the modules will highlight the practical aspects of the technical issues in the modules.
- Each module will be prepared as part of its deliverables to include a self-contained textual treatment that will have quality at the level of a published textbook
- Target audience: undergraduates and first year graduate students in the field of power engineering.

Deliverables

- Appropriate course description and structure .
- Presentation and course materials workbook posted on HU CESaC website with PDF lecture materials to be posted for easy access.
- Interactive session will be available so that PSERC students or other power engineering schools can participate in the class session.
- A joint workshop, seminar or lecture hosted by Apple website thus allowing use of ipod and iphone for real time access during presentation.
- Evaluated course enhancement incorporated into the undergraduate and first year graduate student modules

A Course in Energy Economics and Policy

Task Leader: James Bushnell
Iowa State University

Audience and Objective

- Instruct future energy industry professionals and researchers on the economics of energy markets
- Convey hands-on experience with energy market concepts such as asset valuation, oligopoly competition, exhaustible resources, and market-based environmental regulation through interactive tools such as the Electricity Strategy Game
- Provide exposure to practical applications and networking opportunities through applied case-studies and guest speakers drawn from industry.
- Target audience : future energy industry professionals and researchers

Deliverables

- Course fully implemented.
- Electricity Strategy Game Bidding and Solver fully integrated into a web-based application

Course Development - “Critical Infrastructure Security: The Emerging Smart Grid

Task Leader: Jame Anurag Srivastava
Washington State University

Collaborators: Carl Hauser, David Bakken and M.S. Kim
Washington State University

Audience and Objective

PSERC

- To provide the necessary background for engineering students to work on problems, issues and cyber-security challenges associated with the smart grid.
- The target audience: senior undergraduate students and graduate students with electrical engineering and computer science backgrounds in addition to an online offering to industry

Deliverables

- A comprehensive set of course instructional notes
- Real-world examples and homework problems for each topic area
- A comprehensive set of lecture slides

Broad Analysis: The Information Hierarchy for the Future Grid

Peter Sauer
University of Illinois
at Urbana/Champaign

White Papers

- **Topic A: Information and computation architectures for the smart grid**

  Lead: Lang Tong, Cornell
  University participants: Lang Tong and Pete Sauer (Illinois)
  Industry reviewers: Paul DeMartini, Jeff Taft, and Barbara Fraser (CISCO Systems Inc.) and Annabelle Pratt (Intel)

White Papers

- **Topic B: Networked information gathering and fusion for PMU measurements**

  Lead: Junshan Zhang, Arizona State Univ.
  University participants: Junshan Zhang, Pete Sauer (Illinois), and Lang Tong (Cornell)
  Industry reviewers: Naim Logic (SRP), Shimo Wang (SCE), Floyd Galvan (Entergy), Mladen Kezunovic (TAMU)

White Papers

- **Topic C: Cyber-physical security architectures and algorithms for protective relaying in the smart grid**

  Lead: Manimaran Govindarasu, Iowa State University
  University participants: Manimaran Govindarasu, Pete Sauer (Illinois) and Rakesh Bobba (Illinois)
  Industry reviewers: Jianhui Wang (Argonne National Laboratory), Chen-Ching Liu (Washington State Univ., and Scott Backhaus (Los Alamos National Laboratory)

White Papers

- **Topic D: Real-time, bi-directional communication for AMI in the Smart Grid through wireless technologies**

  Lead: Vinod Namboodiri, Wichita State University
  University participants: Vinod Namboodiri and Ward Jewell, Wichita State
  Industry reviewer: Paul Myrda (EPRI)

Timeline

- End of July 2011 -- First draft of 4 white papers (10-20 pages each)
- End of December 2011 – Final draft of 4 white papers
- Dec. 7, 2011 IAB meeting – report to DOE
- June 2012 – workshop to discuss white papers

Broad Analysis: Future Grid Enablers of Sustainable Energy Systems

Jim McCalley
Iowa State University

Context of this Area's Research

- Objective
  - To *lead thought,* provide context for addressing engineering problems/policy needs
  - Identify research directions
- Overall focus:
  - What are key energy system needs at very high renewable penetration levels
  - Think 2020, 2030, 2040, even 2050
- AGC, dynamic performance standards, environmental costs, transmission, distributed vs. centralized generation

White Papers

Topic	Lead	University participants	Industry reviewer
Primary and secondary control for high renewable penetrations	Chris DeMarco UWisc	Bernard Lesieutre, UWisc Yehui Han, UWisc	Jim Gronquist BPA
Standards associated with dynamics	Marija Ilic CMU		
Cost of minimizing environmental impacts from energy technologies	Ward Jewell Wichita State	Lindsay Anderson Cornell Judy Cardell Smith College	Floyd Galvan, Entergy Jim Price, CAISO Janos Toth, BC Hydro
National transmission design	Jim McCalley Iowa State	Jim Bushnell, Iowa State	Dale Osborn, MISO Doug McClaughlin, Southern Co.
Distributed and centralized generation	James Momoh Howard	Sakis Meliopoulos, Ga Tech	Bob Saint, NRECA

Complete papers by 1/2012

Conduct workshop 6/2012 in Wash DC: Authors+2-3 presenters/paper