Power Systems Engineering Research Center

Panel Session Notes

Future Grid Initiative Workshop

December 7, 2011

University of California, Berkeley

This document provides the notes prepared by Dennis Ray, Deputy Director, PSERC, on the panel presentations during the workshop. There were three panel sessions with the thrust area and broad analysis area leaders. The objective of each panel was to provide background information to the audience in preparation for the posters sessions that followed the panels. The posters are available on the PSERC website. The panels were facilitated by Vijay Vittal, Director, PSERC, who asked questions of the panelists. Notes on the questions and responses are given below. Details about the thrust area and broad analysis work are given on the Future Grid Initiative web page PSERC website.

First Panel Session: Thrust Areas 1-3

9:00 – 9:45 **Shaping the Future Grid: Context of the Research in Thrust Areas 1-3**

- Design options, balancing, and wide area controls
- Control and protection paradigms
- Renewable energy integration

Jerry Heydt (Arizona State Univ.), Anjan Bose (Washington State Univ.) and Shmuel Oren (Univ. of California, Berkeley)

What are the thrust areas that you are leading? Why are they important for shaping the future grid that enables renewable generation technologies?

Heydt (Thrust Area 1): Electric Energy Challenges of the Future

- *Task 1: Integrating Transmission and Distribution Engineering Eventualities*
- *Task 2: A National Transmission Overlay*
- *Task 3: Robust and Dynamic Reserve Requirements*
- *Task 4: Wide Area Control Systems*

Heydt: In my thrust area, we are looking at robust design and robust operation using system theory to solve more complicated problems that may occur in the future. A goal is to find methods for making the transmission more robust to future system events.

Bose (Thrust Area 2): Control and Protection Paradigms of the Future

- *Task 1: Requirements for Hierarchical Coordinated Control and Protection of the Smart Grid*
- *Task 2: Hierarchical Coordinated Control of Wind Energy Resources and Storage for Electromechanical Stability Enhancement of the Grid*
- *Task 3: Hierarchical Coordinated Protection of the Smart Grid with High Penetration of Renewable Resources*

Bose: The control and protection of the smart grid will depend upon the grid architecture so looking at the architecture of the grid will be a very important part of this work. The architecture, communication, and computation for protection and control will depend upon the applications which are unknown right now. In the future, automatic operation of the grid will be more frequent making these different than the controls that currently exist in the operating centers. Issues will include communications latency, data accuracy, among others. The first task is on the architecture itself. Regarding the second task, stability of the grid given the stochastic nature of new generation is the subject of second task. The new generation technologies will rely on power electronics rather than acting simply as synchronous generators. The final task will be to look at how new wide area protection systems should mesh with local area protection systems which we already have.

Oren (Thrust Area 3): Renewable Energy Integration and the Impact of Carbon Regulation on the Electric Grid

- *Task 1: Direct and Telemetric Coupling Renewable Energy Supply with Deferrable Demand*
- *Task 2: Mitigating Renewables Intermittency Through Non-Disruptive Distributed Load Control*
- *Task 3: Planning and Market Design for Using Dispatchable Loads to Meet Renewable Portfolio Standards and Emissions Reduction Targets*
- *Task 4: Probabilistic Simulation Methodology for Evaluating the Impacts of Renewable Intermittency on Operations and Planning*

Oren: Massive penetration of renewables creates uncertainty and variability on the supply side thereby posing new challenges for operation of the grid. There is a new need to harness demand-side flexibility resulting in a paradigm shift to load following available supply. This thrust area looks at ways of implementing this vision. One question is whether centralized markets should be used or whether there should be direct coupling of renewable resources with flexible loads so it seems to the operator that both are behind the meter thus decreasing variability. How should this question be evaluated? Another task is to look at how thermostatically-controlled loads could be used by system operators to provide regulation for example. And another task is to look at how it would be possible to incentivize use of different types of loads to provide operations flexibility. Finally, tools are being developed to take into account uncertainty in operations and planning with flexible loads and storage. This research not only looks at how to make some of these ideas work but also at developing the tools needed to evaluate them.

What are the fundamental building blocks of the future grid in the thrust areas that you are leading?

Heydt: Overbuilding has been the strategy to ensure power system reliability. We now need to look at smart approaches and systems theory to achieve what overbuilding accomplished in the past. We need smarter solutions to attain the desired results. We need to be doing designs up to 2050 to accommodate alternative scenarios, some of which could be dramatically different than business as usual today. There is a need to design the power system to minimize the consequences of such dramatic events.

Bose: Communication and computation are the first set of building blocks in protection and control. Managing data flows is important. Standardization will become a very important issue across the interconnected grid. However, it will be important to accommodate different system designs and implementation (such as in communications) that may develop in different control areas, assuring they work together at the aggregate system level. That's one set of building blocks. Protection building blocks will be needed as well. Digital protection systems have evolved dramatically. The hierarchy of those systems needs to be known if they are going to be connected in a wider area. Some of the issues are arming, predicting, and adaptive settings. On the control side we are now looking new types of controls using power electronics. The algorithms will have to be able to handle aggregated controls of various kinds.

Oren: There are several components. We need better understanding and models of loads to be able to characterize them for use as resources in operations. We also need new load control schemes to mobilize the flexibility of demand resources. Computational tools and capability are also needed to accommodate stochastic loads. We also need tools for simulating the system with thousands of autonomous agents that are responding to prices. What will be the end result of that? Finally, we need situational awareness tools to make use of the data that is being generated and make it helpful to system operators.

Are the building blocks themselves dependent on the type, location and size of generation, energy storage, demand-side resources and overall demand for electricity in the future? If so, how?

Heydt: We need to be also looking at hardware oriented solutions to the problems we are facing. For example, the use of multi DC terminals or polyphase power (e.g., six phase). The use of power electronic controls will become useful as well.

Bose: The biggest hurdle is to have a way to convince people that new technologies work. Controls are going to have to be tested enough to build confidence that they work. This will take time particularly as we test one technology, schemes, etc. at a time. Another innovation challenge is that new ideas are contingent on the availability of other technologies.

Oren: Gaining acceptance of the notion that load can be a resource is an important challenge. Widespread adoption of electric vehicles is an example. New approaches to controlling distribution systems may well be needed. Traditionally we have thought of planning as being a top-down activity. We now need a regulatory framework that provides opportunities for customers with smart meters to make decisions that will affect use as well as supply of electricity. Entrepreneurs can enable the use of demand resources. However, regulators will need to facilitate use of demand resources and provide opportunities to such entrepreneurs. Again, tool development is going to be important to be able to handle a system with so much more diversity and multiple decision-makers.

What are the challenges in developing those building blocks?

Heydt: One major challenge is bringing new technologies to market, addressing the wide-ranging adoption concerns that exist to make sure that power systems are reliable. The human time constant may be the longest time constant in the system. Financing is a major issue. Integration into the system is an issue. Clearly there has to be balance of the costs and consideration of system objectives.

Bose: In our thrust area, we are looking at the edges of control, to see how far controls can be pushed. We need to look at the question, in ideal world, how would you like to be able to control this system with huge penetrations of renewable resources? What kind of communication and computation infrastructures do we need for the next 30 years? Today's architecture was designed 30 years ago. This architecture will not change rapidly.

Oren: Demand response programs grew in the 80s. These programs did not reach high penetration because of the amount of inertia in the industry. There is still a long way to go before a system operator will rely on demand resources for re-dispatch and as a source of system reserves. The intermittency of renewables will drive the integration of the demand-side resources into system operation.

Second Panel: Broad Analysis White Papers

11:15 – 11:45 **Shaping the Future Grid: Context of the Broad Analysis White Papers**

- Information Hierarchy of the Future Grid
- Grid Enablers of Sustainable Energy Systems

Peter Sauer (University of Illinois at Urbana-Champaign)
Jim McCalley (Iowa State Univ.) alleviate letting go to your

The Future Grid Initiative has six Thrust Areas in which a range of research tasks are being conducted to work on building blocks of the future grid. What distinguishes the Broad Analysis efforts from those tasks? What are the objectives of the Broad Analysis efforts? What work is being done? How will the white papers be disseminated? What input is being sought in creating the white papers?

The papers will be shorter efforts and completed sooner than the thrust area research work. The papers will be more discussion-based and designed to engage creative thinking. They will be multidisciplinary, such as engineering, economics, and policy. The outcome from this work will not be solutions or analysis of possible solutions. Essentially the white papers will identify the open questions to reach the future grid. Research gaps or challenges will be identified, but not analyzed as is the case with the thrust area research. Both white paper topics involve identifying research needs to design the enabling technologies. Authors include researchers who are in communications and information technology besides the researchers in power systems engineering. The white papers will suggest where long-term research efforts should be focused.

The Information Hierarchy of the Future Grid white papers are:

- Information and Computation Structures for the Smart Grid
- Networked Information Gathering and Fusion of PMU Measurements
- Cyber-Physical Systems Security for the Smart Grid
- AMI: Communication Needs and Integration Options

The broad analysis white papers for the topic Grid Enablers of Sustainable Energy Systems are:`

- Primary and Secondary Control for High Penetration Renewables
- Standards Associated with Power System Dynamics
- Future Grid: The Environment
- High Capacity Interregional Transmission Design: Benefits, Risks and Possible Paths Forward
- Distributed and Centralized Generation

These white papers will be presented in a webinar series beginning in January 2012. Posters on the topics are currently available on the PSERC website. Academic and industry advisors are providing feedback on the early drafts of the white papers. Authors will also be receiving feedback through the webinars, too. The white papers in the broad analysis area and progress in each thrust area will be presented at the IEEE Power & Energy Society meeting in July. There will also be discussions at a Forum June 27-28 in Washington DC. The Forum will bring leading experts together in a by-invitation event with a mix of people in technical and policy areas. Articulation of different positions will be sought.

Participant comment: Our industry is in the midst of massive changes in technology, policies, customer involvement, etc. A key barrier to change (e.g., adoption of new technologies) is the question of whether the new systems, technologies, etc. will work.

Sauer and McCalley: Underwriter Labs has expressed interest in validation. The ECE department heads around the country have also recognized the changes that are occurring and are pursuing ways to expand integration of the new technologies into their department's education and research efforts. Finally, each of the broad analysis thrust areas will be addressing "paths forward" to address the identified issues and challenges.

Third Panel: Thrust Areas 4-6

2:15 – 3:00 **Shaping the Future Grid: Context of the Research in Thrust Areas 4 - 6**

- Computational challenges
- Resiliency of cyber-physical systems
- Workforce education

Santiago Grijalva (Georgia Institute of Technology), Tom Overbye (Univ. of Illinois at Urbana-Champaign) and Chanan Singh (Texas A&M Univ.)

What are the thrust areas that you are leading? Why are they important for shaping the future grid that enables renewable generation technologies?

Singh (Thrust Area 4): Workforce Development

- *Task 1: Comprehensive Educational Tools for Reliability Modeling and Evaluation of the Emerging Smart Grid*
- *Task 2: PSERC Academy: A Virtual Library of Thousands of Short Videos*
- *Task 3: Synchrophasor Education for Students and Professionals*
- *Task 4: Energy Processing for Smart Grid Technology*
- *Task 5: A Course in Energy Economics*
- *Task 6: Course Development - Critical Infrastructure Security: The Emerging Smart Grid*

Singh: Having a well-qualified workforce is essential whether it is for operation, maintenance, planning, or even for research and education. In terms of the Future Grid Initiative, we are training graduate students as they work on the research. An objective of the Initiative is to educate a broader set of graduate students and also professionals in the energy area. Our effort is working to achieve depth as well as breadth in education of the future workforce.

Grijalva (Thrust Area 5): Computational Challenges and Analysis Under Increasingly Dynamic and Uncertain Electric Power System Conditions

- *Task 1: Decision-Making Framework for the Future Grid*
- *Task 3: Hierarchical Probabilistic Coordination and Optimization of DERs and Smart Appliances*
- *Task 2: Computational Issues of Optimization for Planning*
- *Task 4: Real-Time PMU-Based Tools for Monitoring Operational Reliability*

Grijalva: The work in this thrust area is more than just developing algorithms for computation. It deals directly with the information systems needed to use the intelligence in the smart grid. The timescale of these challenges ranges from milliseconds for transient analysis to years for long-term planning. Distributed computation is going to be very important in the smart grid.

Overbye (Thrust Area 6): Engineering Resilient Cyber-Physical Systems

- *Task 1: Resiliency with Respect to Low Frequency, High Consequence Events*
- *Task 2: Operational and Planning Considerations for Resiliency*
- *Task 3: Improved Power Grid Resiliency through Interactive System Control*

Overbye: Broadly speaking, we have introduced new technologies into our society that are very useful but they are also fragile. Our society is very dependent on the electric grid. How do we make the electric grid more resilient so if there are failures, whether small or large, they grid can ride through them and keep functioning. We are looking at the resiliency of the cyber communication system so that if something fails it doesn't take down the whole grid. We are also looking at ways of keeping the grid resilient with regard to unnecessary cascading outages; that is, looking at ways of designing the grid to minimize its cascadeability. Finally we are looking at resiliency with regard to low probability, high consequence events. In particularly, we are looking at the solar Geomagnetically Induced Currents (GICs) problem, starting off by developing the tools to analyze GICs to decide whether it's necessary or efficient to protect the system from the GICs problem. We are looking at the trade-offs between the cost of doing nothing and the cost of taking action to address the problem: that is, we are developing a tool for risk analysis.

What are the fundamental building blocks of the future grid in the thrust areas that you are leading?

Grijalva: The main focus in my thrust area is on the issue of growing uncertainty and complexity. We are looking both from the long-term planning perspective, from the perspective of hierarchical control issues from the distribution system to end uses and distributed energy resources, from the fast-scale perspective of the use of PMU data to address transient stability issues, and finally from a broader perspective of where we are going with computation in general. A decision framework for the future grid is needed to understand what kind of decisions are needed, when, who and how.

Overbye: We are principally developing tools that will help engineers design a resilient grid. We are doing that by asking what bad things might happen in the grid, what would the consequences be, and what we could do to make the grid more resilient to those events. Alternative ways of making the grid resilient would be the use of microgrids or to consider creating minigrids that split entire interconnection to avoid widespread outages.

Singh: There are four new areas of emphasis in the future of education curricula. Education curricula needs to address uncertainty analysis in ways that it hasn't before. There also needs to be an increase in education on the cyber-physical systems, to produce engineers who can be knowledgeable across communications, computers and power systems. Economics is also important, such as what is the value of reliability. Power electronics is the fourth area.

Are the building blocks themselves dependent on the type, location and size of generation, energy storage, demand-side resources and overall demand for electricity in the future? If so, how?

Grijalva: Architecture is critical to respond to the new uncertainties. The architecture (such as the information architecture, the communications architecture, and the control architecture) need to be developed according to the new objectives of the power system. With the objectives changing, the architecture must adjust. What architectures need to change and in what ways? The objectives that are being set by the industry need to be met by the design of the architecture. The architecture also has to be very flexible. We cannot predict all of the requirements of the future today.

Overbye: We need to be able to have a grid that still works even if some parts fail. We have a great heritage of doing that in the power industry. How do we make sure the system works if the markets fail or if the communications system fails?

Singh: It has been the impression that the lifespan of education is only seven years. We need to focus on the basics so that the students can go out and accommodate the changes quickly. We cannot make education dependent on any particular architecture or technology. We have to give students broad enough knowledge so they can adapt to the situation as it arises.

What are the challenges in developing those building blocks?

Grijalva: In my thrust area, we are addressing challenges in complexity, high performance computing, etc. Research is needed on distributed controls and on processing the massive amount of data that will be available from the high penetration synchrophasors. We are moving into uncharted areas in examining the entire control architecture of the power system of which the IT architecture is only a part. The architecture will also affect the resiliency of the system.

Overbye: Uncertainty, cost, and complexity are the three challenges. We need tools for engineers so they can better analyze future events that could affect the reliability of the system and make decisions about what should be done, if anything. And there are new uncertainties being added to the power system as we add new technologies, such as the communications infrastructure. We need better understanding of the interaction between these new systems and the power system.

Singh: All challenges interact with education. In some cases, research is needed before education can be delivered. Getting the balance between the depth and breadth in a student's education will be a continuing challenge.

What is needed in terms of achieving innovations?

Grijalva: To give the customer the value they anticipate from the smart grid requires the development of the necessary controls. There is a delicate balance between developing the technologies with appropriate architecture on one side and providing value to the customer on the other.

Overbye: Commercialization is key to making the tools available. Understanding the questions engineers in industry are addressing is an important step in developing the appropriate tools.

Singh: Being active in delivering short courses to industry is helpful. Getting feedback on the effectiveness of the education system is important to improving it. Students also need better understanding of the fundamentals before they come to the classroom.