Power Systems Engineering Research Center

Written Comments from Feedback Sheets Made Available to All Participants

Future Grid Initiative Workshop

December 7, 2011

University of California, Berkeley

This document provides the written comments on the feedback sheets distributed at the Future Grid Initiative Workshop. The feedback sheets were categorized by (1) Thrust Areas 1-3; (2) Thrust Areas 4-6; and (3) Broad Analysis White Papers. Transcription of the written comments was done by Dennis Ray, Deputy Director, PSERC, and Theresa Herr, PSERC's Administrative Assistant at Arizona State University. In some cases, it was difficult to read the writing, so the transcription may not exactly reflect the intent of authors.

No.	Research Thrust Area
1	Electric energy challenges of the future
2	Control and protection paradigms of the future
3	Renewable energy integration and the impact of carbon regulation on the electric grid
4	Workforce development
5	Computational challenges and analysis under increasingly dynamic and uncertain electric power system conditions
6	Engineering resilient cyber-physical systems

Instructions to Attendees

As appropriate, circle the relevant Thrust/Area/Task/Topic for your feedback.

1 - Electric energy challenges of the future

A. *Robust and Dynamic Reserve Requirements*
B. *Integrating Transmission and Distribution Engineering Eventualities*
C. *A National Transmission Overlay*
D. *Wide Area Control Systems*

2 - Control and protection paradigms of the future

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

3 - Renewable energy integration and the impact of carbon regulation on the electric grid

- *A. Mitigating Renewables Intermittency Through Non-Disruptive Distributed Load Control*
- *B. Probabilistic Simulation Methodology for Evaluating the Impacts of Renewable Intermittency on Operations and Planning*
- *C. Planning and Market Design for Using Dispatchable Loads to Meet Renewable Portfolio Standards and Emissions Reduction Targets*
- *D. Coupling Renewable Energy Supply with Deferrable Demand*

4 - Workforce development

- *A. PSERC Academy: A Virtual Library of Thousands of Short Videos*
- *B. A Course in Energy Economics*
- *C. Synchrophasor Education for Students and Professionals*
- *D. Energy Processing for Smart Grid Technology*
- *E. Comprehensive Educational Tools for Reliability Modeling and Evaluation of the Emerging Smart Grid*
- *F. Course Development - Critical Infrastructure Security: The Emerging Smart Grid*

5- Computational challenges and analysis under increasingly dynamic and uncertain electric power system conditions

- A. *Real-Time PMU-Based Tools for Monitoring Operational Reliability*
- B. *Decision-Making Framework for the Future Grid*
- C. *Hierarchical Probabilistic Coordination and Optimization of DERs and Smart Appliances*
- D. *Computational Issues of Optimization for Planning*

6- Engineering resilient cyber-physical systems

- *A. Operational and Planning Considerations for Resiliency*
- *B. Resiliency with Respect to Low Frequency, High Consequence Events*
- *C. Improved Power Grid Resiliency through Interactive System Control*

Broad Analysis White Papers

1- The Information Hierarchy for the Future Grid

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

2- Grid Enablers of Sustainable Energy Systems

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

Comments on Thrust Areas 1-3

Instructions to Attendees for "Future Grid Initiative Feedback Sheet for Thrust Areas 1-3

As appropriate, circle the relevant Thrust/Area/Task for your feedback.

1 - Electric energy challenges of the future

- *E. Robust and Dynamic Reserve Requirements*
- *F. Integrating Transmission and Distribution Engineering Eventualities*
- *G. A National Transmission Overlay*
- *H. Wide Area Control Systems*

2 - Control and protection paradigms of the future

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

3 - Renewable energy integration and the impact of carbon regulation on the electric grid

- *E. Mitigating Renewables Intermittency Through Non-Disruptive Distributed Load Control*
- *F. Probabilistic Simulation Methodology for Evaluating the Impacts of Renewable Intermittency on Operations and Planning*
- *G. Planning and Market Design for Using Dispatchable Loads to Meet Renewable Portfolio Standards and Emissions Reduction Targets*
- *H. Coupling Renewable Energy Supply with Deferrable Demand*

Comment Sheet #1:

1C,D = <u>IAB</u>. <u>Wide Area Control Systems & National Transmission Overlay</u>

- National Transmission Overlay is unlikely to ever get funded or built in a reasonable time (less than 30 yrs)
- Better to look at "breaking up" the interconnections with back to back DC or methods. By looking at smaller grid sections with an interconnection-wide control is probably a much better solution. The interconnection-wide control should be able to operate in an autonomous / disconnected mode.
-

2A - <u>Control & protection paradigms of the future</u>. The fundamental protection & control paradigm needs to be re-evaluated. Hierarchical control may not be the best approach. This also relates to the item above (Robust and Dynamic Reserve Requirements, and Integrating Transmission Distribution Engineering Eventualities).

3A - This item I believe has the most merit out of the list of items.

Comment Sheet #2:

1D = Critical that power engineers & computer scientist / communications cultures become better acquainted; great to see the work on wide area and hierarchical control systems. Both communities need to understand the requirements / assumptions of the other. Education is key to solving the overall system solution & solving it effectively.

2A,B,C = Seeing the algorithms to control individual appliances to control variable load is very interesting. Particularly around having all vs. some vs. no information coming back to the utilities, and considering aggregation at multiple levels in the infrastructure.

3A,D = Key to link simulation / modeling to trial deployments - to validate.

Comment Sheet #3:

1C = This subject provides the proper R&D road map for DOE to focus on. All other subjects in the thrust areas become an integrated part to support a national transmission overlay. The technologies to achieve a national transmission overlay - to go from a disparate piece of the grid that is nationally interconnected but interconnected nationally - are challenging (e.g., AC vs DC) but there are no technology show stoppers.

We need to find the institutional / business model for a national transmission overlay, the regulatory and legislation framework for starting a national discussion. The benefits can be significant, similar to what developed with the interstate highway system. These benefits need to be studied and articulated thoughtfully.

Drivers for a national transmission overlay include renewable and nuclear energy integration and delivery to the mega cities of the future, and the environmental issues we need to address.

Comment Sheet #4:

1C = It's something we must have as a nation in order to better assimilate variable sources. But, it raises the question of Federal rights versus State and Local rights. So the answer may lay with politics and lawyers more than with science & eng.

2B = Much more research is needed in this area. But don't draw the line at electromagnetic stability enhancement - FACTS can be used, especially if cost comes down.

3C = Excellent area for research, especially since the cost + practicality of energy storage still needs to be improved.

Comment Sheet #5:

1A = There is a lack of technical information on how much reserve is adequate. There is no good criteria and does not address cost-benefits. Study could address reserve vs. reliability benefits for static and dynamic reserves.

Comment Sheet #6:

1A = With variety of resources and intermittency of resources?

- How can Reserve Requirements be satisfied?
- Planning - What generation (iron in the ground) can be guaranteed available over multiple years? Will markets provide incentive for ancillary reserve products?
- Operations - What is right mix of reserves to satisfy reliability? "x" percent renewable, "x" percent fossil etc....

1B = National Overlay - This could be beneficial if accessible by multiple Load Serving Entities. Also, an overlay must be designed with generating resources locations either pre-determined or forecasted to a high degree of certainty.

Comment Sheet #7:

1C,D = Special Protection Systems (SPSs) seem to be frowned upon by NERC, yet this research seems to indicate or assume that complex protection schemes will or should be even further implemented. Will NERC be on-board with more SPS's? How will reliability standards and requirements be impacted?

2A = Many complex protection schemes mitigate problems that could be fixed with more expensive transmission reinforcements. What are tradeoffs between more complex control and protection versus building more transmission infrastructure? Where is the breakpoint between the two? What factors will influence this?

Comment Sheet #8:

1C = Consider a DC backbone overlay which would allow fast controls to be implemented.

1D = Wide area controls should work in harmony with & be coordinated with local substation - and master control.

1B = Improved operational coordination between the low & high voltage monitoring and control systems will likely improve reliability. Many originating disturbances begin in the low voltage system.

2 = Consider impacts of market systems, AMI, DER, Electric Vehicles, decentralized substation control.

Comment Sheet #9:

2 = How will new control and protection systems be tested and evaluated? It will be key to provide evaluations of these new schemes.

3D = Need to account for modeling differences between electrical and thermal systems. How do we model integrated systems on various time scales (see → hours).

Comment Sheet #10:

1A = + (good)

1B = - objectives not clear

1D = + (good)

2B = ++ Good work - can be the [co?a??????ve] for integration of renewables in the future

Comment Sheet #11:

1,2,3 = Overall feedback: A benefit may be importance of each technology. An actual rating, say 1-10. Also, a second rating, of implementation ready research, (1-10). These two ratings may help plan for the future grid. Which technologies to focus on. NASA uses a similar method.

Comment Sheet #12:

3D = This project studies at the practical implementation of coupling renewable energy supply (especially wind) with deferrable demand. I really like it because of the real case study using CAISO model. It considers low frequent event such as loss of generation with different scenario of wind outputs. The suggestion would be to consider at the same time, the maintenance of transmission system impact to above scenario studies.

Comments on Thrust Areas 4-6

Instructions to Attendees for "Future Grid Initiative Feedback Sheet for Thrust Areas 4-6

As appropriate, circle the relevant Thrust/Area/Task for your feedback.

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

5- Computational challenges and analysis under increasingly dynamic and uncertain electric power system conditions
1. *Real-Time PMU-Based Tools for Monitoring Operational Reliability*
2. *Decision-Making Framework for the Future Grid*
3. *Hierarchical Probabilistic Coordination and Optimization of DERs and Smart Appliances*
4. *Computational Issues of Optimization for Planning*

6- Engineering resilient cyber-physical systems
- *Operational and Planning Considerations for Resiliency*
- *Resiliency with Respect to Low Frequency, High Consequence Events*
- *Improved Power Grid Resiliency through Interactive System Control*

Comment Sheet #13:

4. Based on some of the panel discussion comments by Chanan Singh, suggestion for education topic - It was mentioned that one of the challenges in education in this area (cyber-physical) is that the people who are teaching it do not necessarily know enough about it because it's so new & there just isn't all that much out there. I think it would be useful to encourage / find ways to facilitate students teaching other students. As a recent student, I think a lot is learned this way. Students learn fast and might be better teaching each other some of those interdisciplinary things by <u>collaborating with other students in different areas</u>. Then these students have made themselves the cyber-physical / interdisciplinary experts and can go on to teach <u>others</u>. Ex - TCIPG Trustworthy Cyber Infrastructure for the Power Grid - utilize students in there & previous students from that program. I guess it is difficult to teach interdisciplinary work in a top-down way like in normal courses, so it is a good idea to strongly teach the fundamentals (as was mentioned) but then let students teach each other - learning in a cross-collaborative way by working together with students in different fields. So in summary, the suggestion is to encourage student cross-disciplinary collaboration to help meet those education needs. This would help create the workforce with smart grid skills. An example that was discussed today was senior design projects.

Comment Sheet #14:

4A = very useful. 4B = very useful. 4C = low priority. 4D = good. 4F = Good.

Comment Sheet #15:

4 =

- Imperative to create educational materials, not only for students with the potential to join the workforce, but also those whose disciplines / expertise is in an adjoining or complementary area (e.g., teaching cyber security to power engineers, or teaching synchrophasor issues to computer networking operators, or etc.)

- Additionally, it's important to invite policy makers to those venues; this is not only a cross-disciplinary challenge, but also a cross-organization challenge (government, industry, academia, utilities)

5.2 & 6B = > Both point to decentralization

Comment Sheet #16:

4 = Grants should be made available to groups of university consortia to establish large scale digital simulation and modeling capability to support both education and research. The future in understanding systems, system integration of components and systems of systems behaviour will come from better tools for modeling and simulation and hardware / controller-in-the-loop, rather than build hardware for testing.

5 = Co-simulation of electrical, communication, information, protection and thermal will be needed to understand the system of systems and allow what-if analysis. Robust (bandwidth) and validated models are needed for this.

5 = Uncertainty in models and component and system information can be modeled and understood. Larger complexity of systems and systems of systems can be modeled larger scales M & S infrastructures in the universities.

Comment Sheet #17:

4E = We will continue to need multi-discipline expertise employees. But do add CIS into this.

5A,5C = The PMU will provide a whole new paradigm in power system monitoring. We need to learn more about how to use and benefit from this resource. This area is ripe for improved optimization.

6A, 6B = Great areas for research. We address this now to some degree, but new knowledge would be really helpful. LFHC events should be looked at - but don't duplicate what EPRI is already doing. Hopefully the PSERC Univ are working with them.

Comment Sheet #18:

4E = This area is very weak and industry can benefit significantly by improvement in this area.

Comment Sheet #19:

4 = Workforce Development

- Education on PMU (Synchrophasors) will provide the basis for many future grid initiatives.

- Courses showing how PMUs and Smart Grid Technology fit with Distribution networks control and Wide Area operations are needed. Raw PMU data is of little use without applications tools.

6 = Engineering resilient cyber-physical systems.
Presently, these topics are detailed empirically in technical reports. Case studies showing plausible resolution and potential remediation are needed that simulate electric system (mechanical simulation if appropriate) effects.

Comment Sheet #20:

6 = What is the best way to implement new design requirements? Reliability Standards? Individual utilities doing risk assessment? The better the risks can be quantified and validated, the easier the business case to spend money to mitigate.

Comment Sheet #21:

4A = Very important work - a necessary part of closing the talent gap the industry is facing.

6B = Very poor use of PSERC funds - appears to be too closely linked to the promotion of the Power World product.

6C = Excellent! Much needed work.

Comment Sheet #22:

4A = Learn from existing online public courses that are availlable today (Ned Mohan, Overbye, etc) Why & how are they [?] used? How do we enhance its actual use - marketing? instructors / webinars to introduce them to the library?

5B = This is where the rubber hits the road - grid operators want better dynamic load models to help improve decision-making control with fast sub-second measurements.

Comment Sheet #25:

I really liked the commercialization of the tools that Dr. Tom Overbye mentioned in his panel discussion. It is the fundamental of the success of new technology. A tool helps the user, generally does not have the depth of knowledge on the subject, to understand the complex issues and consequences relatively easy.

Commenter #30:

6B =

1) Seems to have an inordinate bias towards geo-mag. storms. An example of a resilient system was the 'Sendai' microgrid that kept powering local loads during the tsunami earthquake event in Japan; Another example is the UCSD microgrid that powered the campus of UCSD during the 9/8/11 blackout of San Diego.

2) CPS for end-users in the form of self-learning EMS for office or home energy systems that interact with the information obtained from the grid without constantly involving customer [IP] is important. But this was not discussed at all.

Comments on Broad Analysis White Paper Posters

Instructions to Attendees for "Future Grid Initiative Feedback Sheet for Broad Analysis topic/white paper

As appropriate, circle the relevant Thrust/Area/Task for your feedback.

1 The Information Hierarchy for the Future Grid

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

2 Grid Enablers of Sustainable Energy Systems

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

Comment Sheet #23:

1C = The topic needs to address the "out of band" control plane to actually manage all the SG infrastructure. Also the effort should at least consider the different domains of the GRID and their "speed" or "latency" requirements. Transmission usually requires high speed information signals & also control actions (such as protection). Distribution has lesser requirements and then customer is probably even lesser requirements but greater privacy issues.

Lastly the actual "wired" networks probably needs to be a blend of utility-owned/private primary network for essential "power grid" operations. Then a second network that augments the primary are for additional information such as asset health or other data. Then a third network for "meter" data. Lastly a fourth network for "network services" such as firmware upgrades, and other performance tools. Each network has its associated service level agreement.

Comment Sheet #24:

1B = Important to think of the "Internet of Things" (that is, communications & intelligence everywhere in everything) as playing into the command and control of the Smart Grid & the infrastructure it necessitates. Think about the architecture that extends all the way out to the edge devices.

Believe that distributed generation storage & control is essential to a truly Smart <u>and</u> Robust grid.

One cannot really design a believable architecture without thinking about the market or economy that incents that design; therefore, you need to list the assumptions & the requirements for the architecture upfront, along with the economics associated.

Comment Sheet #25:

1A = Cyber-physical system security technology could be utilized in other industries other than the power industry. It is well a thought project which targets to deal with new challenges to the reliability of the power system.

Comment Sheet #26:

2 =

- Do we have enough / too much generation?

- There are major questions to be answered before an answer can be acquired [to this topic of grid enablers of sustainable energy systems].

- Demand Response may have low availability or not sustainable with market prices.
- Renewables may not survive in a market environment. Will the tax credits continue to be needed to build / maintain renewable sources.
- What is the life expectation of wind turbines, solar systems, energy storage?
- Peaking turbines are not designed to run as base load. (Just because natural gas becomes the primary fuel, peaking turbines will not replace coal when units are base load.)
- What is design of renewable resources?

Comment Sheet #27:

2D = The big questions are: who pays, and who will build it? Long lead times and political/economic changes probably make development of a transmission overlay appear very risky to private investment.

2E = How does the grid need to be designed in order to take advantage of reliability benefits of local generation? Could this result in “excess” generation or transmission capacity as compared to a system that depends on interconnected resources? Utility systems were originally designed around local generation and have migrated to the larger interconnected system presumably due to economies and reliability. Also, how could distributed generation be implemented for reliability reasons, considering that generation is now primarily driven by the market?

Comment Sheet #28:

2A = Significant research and application needed to utilize this. This could be a standard feature and can significantly benefit industry. With these features developed, the renewables can be looked as improving system performance rather than being a burden to the grid.

Comment Sheet #29: It would be helpful if the white papers acknowledged other institutions efforts in these areas, critiqued what those institutions are doing well, and where there are holes across institutions. For example, NIST is working on grid interoperability standards, and PNNL/DOE has a group working on cyber-security standards.