Power Systems Engineering Research Center

Notes from the General Session Discussions*

Future Grid Initiative Workshop

December 7, 2011

University of California, Berkeley

The purpose of this document is to provide a record of the ideas and perspectives expressed during the workshop. In part, the record is designed to provide feedback to the researchers in the Future Grid Initiative. It contains working notes and flipchart entries from general discussions. For the flipchart entries, comments have been categorized during the compilation process. This means that some comments may appropriately be assigned to other categories depending upon the reader's perspective. The notes and comments generally reflect what was said during the discussions, but there may have been some communication errors in the transcription process. The reader is encouraged to visit the PSERC website to see the actual workshop agenda, supporting materials and posters.

Opening Session Discussion Following Presentation by Vijay Vittal (8:30-9:00 am)

System Operations

1. What is the future of the principles that NERC uses? Will criteria or operating requirements change?
2. NERC criteria may need to be revised.
3. What should the performance requirements be for all players (e.g. generators, transmission owners, demand response, etc.)
4. Dispatchable intermittent resources. MISO is dispatching wind, wind bids into market at >0 price.
5. Capacity adequacy, flexibility metrics are being developed in a NERC task force. MW/min to manage renewables.
6. Mandated performance requirements for different players, e.g., reactive power supply by renewables, demand response requirements.
7. New operational/planning footprints? The larger the control area, the easier it will be to manage the diverse resources.
8. Need to rethink the way the power system should/will work. Example, forecasting: what do we need to forecast? Why? Look at what we are doing today and ask what needs to change.
9. What should the new dispatch policies be to enable wind (MISO DIR program as example, 2000 MW registered for that program.)?
10. Footprint: larger system makes the system easier to manage.

*Compiled by Dennis Ray, Deputy Director, PSERC. Discussion notes were taken by Lindsay Anderson (Cornell), Judy Cardell (Smith College), and Ward Jewell (Wichita State).

Data

1. What are the appropriate metrics of the grid? Knowing this will contribute to identifying data needs.
2. What are we going to do with the new real-time data? Is it all needed? What data are needed? Can it be actually useful in critical decision-making?
3. Data quality should also be considered.
4. Data access
   - Who gets access?
   - Do the export laws have any effect on who gets access and on how access is controlled?
5. New data from synchrophasor installations also coming from the ARRA projects. How do we make use of synchrophasor data that's emerging?
6. Data from PMUs also starting to be very important at transmission level.
7. Data is coming in, being stored only for use if there is a problem. More data will be coming in. Do we need all this data? msec level data may not actually be usable. Consider these and then decide what data is needed and then start designing the communications network.
8. What are the appropriate metrics of the grid? Knowing this will contribute to identifying data needs.

Capabilities and Properties of the Future Grid

1. New properties of the Future Grid?
   - Will the N-1 criteria still exist? If so, how will the system respond to contingencies?
   - Flexibility
   - Resilience (how should degree of resilience be measured?)
   - Reliability (what will the meaning of reliability be?) Uncertainty will no longer mainly be “binary”.
2. What will the "grid architecture" be?
3. Need vision for IT architecture that supports the grid.
4. IT architecture needs to be based on the future grid vision
5. How do higher penetrations of variable generation affect systemwide capacity needs?
6. Need to architect the power system before we develop the IT architecture (e.g., centralized versus decentralized generation, transmission overlays, hybrid,…)? Need common understanding of future system.
7. New properties of system; flexibility of the system. The nature of a contingency changes. How do we measure resilience? Quickly detect a situation and recover. No longer binary: N-1.
8. Flexibility adequacy/metrics needed: NERC Integrated Variable Generation Task Force
9. Should we conceptualize the future grid assuming a legacy grid? How much of a legacy system should be taken as given? What are the implications of a different definition of legacy?
10. The generation resources in the future grid need to be understood (operating characteristics, operating costs, etc.). What roles for each resource? How do the different resources participate in a market?
11. Uncertainty about how the smart grid will evolve
12. Need for technology demonstrations or pilot studies at utilities
13. PSERC has built a very good case. The weak point is the assumption that the legacy grid must be part of the future grid. Maybe a different look, a clean slate, is needed. Challenge the legacy grid.

14. How do we determine the architecture of the IT systems before we know the architecture of the future grid power systems. Europe is moving to a more decentralized system.
15. Grid Architecture work is being done. Vision is needed for IT architecture as well. Usability is critical.

Markets, Customers, Demand Response

1. Markets: how to model different types of markets in a region or interconnection?
2. Conceptualizing the future grid technologies/building blocks also means conceptualizing the power markets (e.g., RTOs). Can the legacy market areas/types be maintained? What would the new seams issues be? How will the different markets/RTOs communicate?
3. New role for customers in the future grid. Many new players. How will they behave? How will they respond to incentives (e.g., prices)? Are our assumptions correct? Behavioral science research opportunities.
4. How will demand resources be used? Should demand resources be treated the same as generation resources?
5. Need for and use of information about dynamic pricing. Will take time to determine lessons learned from ARRA projects.
6. Regulators seem to be treating demand response as a generation resource. This may be a dead end approach, and we should think of demand as demand. Demand should be considered in market design.
7. Participant behavior will have a big effect, may need to be added.
8. Investment cost intensive resources vs. fuel cost intensive resources. How do these two participate in a market fairly?
9. Information from ARRA dynamic pricing projects is going to be helpful if it is made available and analyzed.

Financing, Cost, Investment, Value, Business Plans

1. Technical approaches for the future grid need supporting business plans
2. What's the value of the new capabilities in the future grid? Value needs to be understood before making capital investments in the future grid and its new technologies. Need to optimize investments.
3. How do we meet financial constraints of utilities, customers, etc. in trying to meet the technical challenges of the future grid?
4. How to provide sufficient certainty to secure financial investments in new resources?
5. Cost of the future grid? Who is going to make the investment? This is often the focus of discussion rather than vision, technology, etc.
6. How do we prioritize, rollout, make decisions on what is to be built? What are the appropriate metrics for prioritization?
7. Economic value of reliability. What is it worth?
8. Need for regulators to support cost recovery to enable investment in new technologies for the future grid. Regulatory changes will be needed because historical policies for approving costs may not apply or may not provide the incentives needed to develop the future grid.
9. Economic value of reliability. We now design against a benchmark. The actual value is difficult to quantify but needs to be understood.
10. Solutions must meet financial resources of utilities and ratepayers.

11. Sound business plan must be included with anything that is produced. Pilot studies must be done to develop these. Export laws will be an issue: who can see the data.
12. What is the cost, who is going to make the investment? Standards and metrics for data are needed. Market is ahead of standards.
13. What is the value of all these technologies to the utility? The value needs to be quantified.
14. We do a better job of economics at utility level but not in the area of public goods. This will be an important issue and this is a good place to study it, e.g. resiliency, carbon.
15. Incompatibility between current regulations and new technologies. Utilities cannot recover costs under current regulations.
16. Seam issues, market differences. Communications between companies is difficult because of this. Different smart grid designs among companies and regions may make this even worse.
17. System operator: financing certainty for renewable resources. Very important to security.

Workforce, Engineers

1. How can we make engineers more productive? What tools can be provided? How can teams be organized?
2. Need for super engineers who are multidisciplinary and who are able to work in multiple domains
3. Forecasting skills for engineering needed
4. Meteorology is also needed in the renewable and power engineering community.
5. We need engineers familiar with power systems and information science and digital technology, and how those systems work together.
6. Workforce: needs more knowledge than in the past (e.g., renewable energy, meteorology,…)
7. Guiding principles: simplify what we do. Many years are needed to develop a power engineer. We should design the tools to make it possible for those with less experience and expertise to plan and operate the even more complex future grid.

Discussion of Posters in Thrust Areas 1-3 (10:45-11:15 am)

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

Capabilities and Properties of the Future Grid

1. Transmission overlay: important issue for future grid
   - Voltage level?
   - DC?
   - Consider "energy" overlay
   - Need to be looking for the biggest bang for the buck!
2. Knowing “where we go from here” is important. How do we get a national commitment to a vision of the future grid?
3. Technologies already exist to address some of the challenges in creating a future grid.
4. Is there a community that would agree to standards, technology choices, etc. that would be included in a future grid vision?
5. Driver of automation: is it minimizing the cost to consumer or the return for investors?
6. What is the total portfolio of needing building blocks for the future grid?
7. What is the total system architecture?
8. What is the minimum level of reliability to prevent cascading outages?
9. Tolerances in frequency deviations may be too high. Push quality criteria closer to the consumer.
10. Design for verifiability performance (metrics?) May need control trade-offs. May not want best “average” performance for the system. Verifiability requires more metrics.
11. Design issue: automation versus manual control. Is minimizing cost the real driver of this choice?
12. Design issue: totally operator-free environment?
13. Need total system architecture specified to determine what control strategies are need.
14. Should the future grid vision be one of all decentralized decision-making? Note: the grid would have to enable this.
15. Is the existing transmission grid overbuilt? The original designs were very conservative. Or is there a general agreement that the transmission grid is too weak?
16. Seems to be a consensus that the grid is underbuilt. Who is going to push for fixing the system?
17. The distinction between transmission and distribution is important. Some of the existing distribution system is underutilized. Efficiency and improved grid utilization considerations should be given more attention.
18. Use a transition process to the future grid that applies future grid concepts along the way – perhaps to particular groups, sub-divisions, shopping centers, neighborhoods, regions. That can be the way to fund the future grid.
19. What grid operation metrics (e.g., frequency) can be changed?

20. Tolerances in frequency deviations may be too high. Push quality criteria closer to the consumer.

Markets, Customers

1. Need to involve the consumer in the designing the future grid. Affordability is an important issue. Will consumers be willing to pay additional costs if there are choices that could be made to avoid them? What are the drivers for the smart grid/future grid?
2. Lay person education is important. Need for education about smart grid
3. Smart grid empowers consumers. Provides consumer choice.
4. Winners and losers in deployment of smart grid. Some groups are opposing smart grid deployment. Perhaps education/outreach will convince consumers that choice is a good thing and worth paying for.
5. Smart grid will enable customers to choose how much reliability they want.
6. How much are consumers willing to pay for choice or "empowerment"?
7. Outage costs to consumers too often ignored in investment and grid reliability decisions.
8. Do consumers have input in investment decisions?
9. Future vision: do we need a highly reliability grid or should consumers do what they need to get their desired level of reliability (e.g., use of microgrid)?
10. Design issue: make reliability a private good? Can the smart grid make reliability and customer choice. Consumers could choose the level of reliability they want rather than a central decision on how much reliability everyone needs.
11. Can we relax the reliability criteria if we let consumers decide what level of reliability they want and are willing to pay for? Many free riders today.
12. Push quality criteria closer to the consumer.
13. What is the minimum level of reliability to prevent cascading outages?

Policy

1. Transmission overlay: important issue for future grid
    - Public good dimension: serves everyone simultaneously
    - Fairness issues: how is it paid for? Who pays?
    - How to involve the consumer? Should they pay more? What's the value to them? How much do they want to pay for the functionality of the future grid?
    - The institutional, regulatory and statutory obstacles can be significant.
    - Chasing beneficiaries for grid investments is a difficult and perhaps wasted effort.
2. The institutional, regulatory and statutory obstacles can be significant.

General Comments About Planned Research

- Observation: Planned activities relate to real world problems. Creative approaches being taken.

Working Notes from the Discussion Session on Thrust Areas 1-3 (10:45 and 11: 15 am)

Participant: Transmission overlay is important part of work. This is the most challenging part, down the road will be the biggest bang for buck, compare to the interstate highway system, which had unintended major benefits for the country and economy. The same can be said for the transmission grid. Not so much a technical problem, obstacles are the institutional and regulatory obstacles (and legal - state v. federal government). See interest in even expanding this study of the national transmission overlay. And to a HVDC overlay

Heydt: History of the so-called national grid. In 1970s the utilities opposed this. Then it seemed to fade away. National Energy overlay, not only electric, but coal, natural gas, etc., as well is worth investigating. Jim McCalley is looking at this to some extent.

Oren: Discussions with FERC, post Order 1000, need to be looking at transmission as a national good. Opposition - why should people in Midwest pay for a transmission system that will then only take their cheap power to California? May be politically infeasible to get to the point of seeing the transmission backbone as a major national infrastructure and public good.

Participant: Nice to see that none of the ongoing work (from poster session) is purely abstract work

Participant: See need to involve the consumer more. Looking into the future we see electricity bills going up, there is a lot of interest (political) to keep energy prices low. What is the driving force behind the smart grid? Opposition - the elderly will not be able to utilize it and see their bills go up. We need consumer and lay person education to gain acceptance.

Oren: There are always winners and losers, and so there will be some losers with the smart grid. The cell phone industry is a good example - empowering consumers has worked. But we do need consumer education - we are giving them a choice, and this is good - we are giving them something, not taking things away

Participant: Advanced control, issues of designing for verifiability of performance, even if this means a trade-off with some average performance, we can look to the aircraft industry. Verifiability needs more measurement, more feedback, not necessary to improve the control, but to be sure we get what we want. Also true for markets. May need to not design for best average, overall performance, in order to ensure verifiability

Heydt: Hopefully we can more toward the operator free environment.

Vittal: Operators do not like this.

Jerry: Probably earlier telephone operators did not like this either.

Oren: The power of technology is to make reliability a private good. Smart grid is moving us in this direction. People can choose the level of reliability that they want, rather than an engineer deciding this for everyone.

Participant: What is going on is good, but what else, what other research needs to be done to achieve the desired results of the larger DOE project? What else would it take to meet all the program requirements.

Anjan: For now we are just trying to investigate a couple of things, and of course there are many holes left for what needs to be investigated.

Participant: Agree that we are building the infrastructure to pursue reliability as a private good. So why should be build a transmission backbone to the high (NERC) reliability standards? We should consider relaxing the reliability standards as the transmission backbone is designed and then eventually constructed. People who want higher reliability for themselves can invest in a local microgrid. So how much of the reliability requirements can we outsource to the local consumers?

Shmuel: What is the minimal level of reliability required to prevent cascading outages - we need to define this. The tolerances we allow in the f deviations are way too tight. In India, they allow 2Hz frequency deviation. Perhaps we do want to push this requirement to the consumer.

Heydt: Automation vs. operator control vs. something in the middle. The customer isn't driving this at all; it is the people providing funds for the IOUs, and want to continue to serve the customer at minimal cost. That is more of a driver to automation than the consumer asking for this directly. Sees the investors as driving automation, not consumers

Bose: Yes we want to empower the customers, but if they end up paying 30% more, then it is not going to happen.

Oren: Much of the calculation of cost rarely takes the cost to consumer into account. It would be cheaper, during blackouts, restoration, etc, if there were a group of customers who agreed to lower reliability and so were blacked out first, restored later... and this would have made dealing with the west coast blackout easier and cheaper. It is not clear that protection of generators is a better economic choice than blacking out San Francisco for 24 hours.

Participant: Would be nice if we were able to get everyone to agree - gov't, consumers, ... - which would then mean that moving forward, investing in smart grid, would be straightforward. Alternative: to design the systems and subsystems per need. Example: take one subdivision, and if the developer of the subdivision has provided for backup, then those consumers don't care about the reliability of the remainder of the grid. And consumers won't care about what the actual system architecture is. Suggest that the transition can be gradual, as we're doing, and take special care to design specific, specialized grid architectures to serve needs of specific subgroup of consumers. Subdivision, industrial plants, ...

Participant: Has heard comments that we are overbuilt (transmission system). Is this actually true?

Heydt: Perhaps we were before, but not as much now.

Bose: Around country, essentially everyone agrees that we are not overbuilt anymore. And nobody seems to know who ought to fix things. Is it FERC, NERC, who? Who is responsible for fixing the transmission facilities. On the distribution side, we are finding that many parts that are only 30% loaded, and while some are 80% loaded, even on the same system with the phases loaded differently.

Discussion of Posters in Thrust Areas 4-6 (4:00-4:40 pm)

No.	Research Thrust Area
4	Workforce development
5	Computational challenges and analysis under increasingly dynamic and uncertain electric power system conditions
6	Engineering resilient cyber-physical systems

Computational Challenges

1. Need for new load models that are accurate for better modeling, particularly in a decision-making framework. There is a particular need for load models for dynamic modeling. Operators need to able to believe the data and the models.
2. Massive amounts of data are becoming available: needs mining and use.
3. Formal validation of load models can be done using the new data.
4. Modeling more challenging in distribution systems and Microgrids. Do we really need models if we have massive amounts of data available?
5. Modeling issues: validation, complexity, data quality, verification. Need to be able to model transient events, short time-scale.
6. Models: Is the data available? What is the quality of the data? Is it good enough?
7. Modeling issue: What tools are needed?
8. Modeling issue: Trend toward distributed systems and controls (e.g., self-energizing microgrids). More flexible distributed controls may be a natural way to create a reliable system with wide-scale penetration of sub-systems. What is the best architecture?
9. Consider extending work on autonomous controls in other areas to power systems
10. Need to look at use of greater computing power (e.g., EV modeling and control). Will modern computer power capability help overcome computational challenges? Issue: massive amounts of data and devices for control. How do we coordinate millions of EVs? Dynamic stochastic optimization will be important.
11. Alternative: distributed computation (how to deploy?). How this substitute for the need for more high powered computation. How do we distribute the intelligence?
12. Communication lags and latencies: that's the constraint on ISOs, not lack of computing power. Particularly an issue with large control areas, perhaps crossing multiple systems. Autonomous control approaches can reduce communications issues.

Resilient Cyber-physical Systems

1. There is value in developing simulation models of Geomagnetic Induced Currents. Validation is important. Currently there is a lack of good analytical tools. Don't want to wait until there is a catastrophic event.
2. State estimator models should model the impact of GICs.
3. Should also consider other credible events: hurricanes, earthquakes, etc. Many are once in a life-time events. Existing models may work in those cases. GICs needs new modeling effort.
4. What about large-scale cyber events? Are we able to model those?

5. Value in identifying the high consequence, low probability events (NERC has done this such as for a pandemic).
6. What is the response to such events? How do you build a grid considering such events? How would consideration of those events change our planning? When do we build the grid differently to withstand particular events?
7. Tools needed to help decide how or whether to respond to particular event.
8. Need magnitude metrics to be able to categorize high consequence events

Workforce Development

1. Is there a need for better quality students going into power engineering?
   - Student quality has been improving. It is education itself that needs improvement.
   - Student quality is really the same as before, it's just that the students need different skills than before.
   - GPA of incoming students has been rising.
2. There is a need for multidisciplinary, multiple domain graduates, but the education system itself poses constraints on achieving that. Smart grid technologies require different knowledge and skills, for example. How to change the education system? How do we create a workforce that is prepared for the smart grid functionality/technologies and consumer interactions.
3. U.S. system provides broader education than other countries.
4. Future hiring strategy may be to hire students that have some breadth beyond power engineering. Students need to speak the different "languages" of the smart grid.
5. Current curriculum does offer senior capstone projects that can be multidisciplinary, and on current technologies.

Discussion Notes from the Session on Thrust Areas 4-6 (Q&A between 4:00 and 4:30 PM)

1. Geomagnetically induced currents. Verification of models using data is very important.
2. Hurricane, earthquakes, etc. are major events. Why focus on geomagnetically-induced currents (GIC)?
3. We need to improve the quality of students entering electric power engineering.
4. Load modeling using advanced data techniques is also an issue that needs to be addressed.
5. Are you planning on looking at other low frequency events in addition to GIC? NERC has addressed some of these, like pandemic.
6. What is the cutoff for designing the system to respond to a low probability, high consequence event?
7. Model bandwidth is also important in validating models.
8. Will part of the computational challenges scope be to identify the computing technology needed?
9. ISOs have enough computing power and speed. The issue is with communication lags and latencies. It takes too much time for control signals to travel both directions. Autonomous control – distributed computing - would help with this issue.
10. University departments' historical separations by departments and areas are problems for smart grid education.
11. Senior design projects and other similar experiences are a good place to expand education across areas.

Discussion of Posters on Broad Analysis White Papers (1:45-2:15 pm)

White Paper Topics:

Grid Enablers of Sustainable Energy Systems

- Primary and Secondary Control For High Renewable Penetrations
- 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

The Information Hierarchy for the Future Grid

- Cyber-Physical Security Architectures and Algorithms for Protective Relaying in the Smart Grid
- AMI: Communication Needs and Integration Options
- Information and Computation Structures for the Smart Grid
- Networked Information Gathering and Fusion For PMU Measurements

The Information Hierarchy for the Future Grid

1. Need to think broadly about the information architecture including massive device IP addresses and pervasive computerization. Devices may be able to communicate with each other, each having an IP address. An IP architecture needs to considered. Will the home become its own Microgrid?
2. What is the umbrella control architecture? What does the grid look like if independent initiatives are all implemented? How does it all fit together? What happens if the separate initiatives are combined?
3. In thinking about the information architecture, consider existing organizational efforts. Example SGIP organized by NIST. How will these separate organizational efforts be integrated? What do they have in common?
4. Distributed architectures: define a sub-system and then the boundary conditions that would allow for integration with other sub-systems. Bottom-up approach: how would it unfold? How to you specify a sub-system that interfaces with other sub-systems? How is interoperability? Need specification of interoperability standards for layers that are already specified.

Grid Enablers of Sustainable Energy Systems (System Architecture)

1. Market design problem: need consideration of zero marginal cost generation. First generation market design capacity incentives may not work in the future. Need market design that incentives capacity additions. Redesign may be needed.
2. Example: BPA's 2011 summer experience with negative LMPs. Hydro and wind conflicts along with run of river issues.
3. Scenario analysis is needed. Must consider disruptive changes (such as no nuclear, new technologies or significant policy changes, e.g., zero carbon emissions).
4. In developing a system architecture, must be very clear about the drivers of the future grid design.

5. Problem with architecture development is conflicting objectives (e.g., low-cost/economics, environmental objectives, reliability). Need to be very clear about driving objectives and their priorities.
6. New analytical tools will be needed.
7. National transmission overlay – may only be certain regions that need the overlay.
8. Microgrids at the transmission level – but integrated. Need to consider the spectrum of possibilities for a national grid.
9. Microgrids in Korea: high powered grid, home, EVs, wind and solar.
10. New techniques/tools for optimization may help with meeting multiple objectives.
11. Interacting regulations may also make reaching multiple policy objectives difficult.
12. Design Issue: can systemwide synchronicity requirements be relaxed? This may make it easier to meet multiple objectives, addressing integration of Microgrids/sub-systems.
13. Can storage substitute for high voltage transmission?

Working Notes from the Session on Broad Analysis White Papers (Q&A between 1:45 and 2:15 PM)

Participant: Challenge is to think even more broadly at what the digital fabric of the future grid will look like. Perhaps every device, down to the bulb level is IP addressable, and there is intelligence in rooftop inverters. You can see light bulbs negotiating with rooftop solar. We should really be thinking about the hierarchical architecture that is required to knit all these things together.

Sauer: It is true that this intelligence is coming. Venture Capitalists are already thinking about the next generation of technologies. Will every house be a microgrid? Consider the Korean's main concepts of the future grid: electrification of autos, wind and solar, the home domain, The grid itself (high powered). In Korea, they are aggressively marketing this concept with brand new appliances with enabling technologies built in. In the future, perhaps each home is microgrid.

Participant: It is great to see the list of initiatives , and what is going on in industry. PSERC can play a significant role by projecting ourselves 5 years down the road and assume these initiatives bear fruit. Then what will the grid look like? What kind of monitoring architecture will be required? We have PMUs, synchrophasors, what about AMI, DER. Maybe we should be looking at a white paper that combines these initiatives and describes what the future will look like.

McCalley: Perhaps it is a good plan. What is the method?

Participant: There are reference architectures in existence. Maybe we should take them and assess them to discuss how similar or different or are there. The Smart Grid Interoperability Panel has developed one. NIST brings a lot of industry together, has a reference architecture group. Is there something common among them that we should be looking at more closely?

Participant: We should also explore the idea of defining the distributed architecture by giving the architectures of sub systems to define the boundary conditions for other systems. How would this bottom-up approach evolve? Layers of definition to make systems interoperable…as a group we could define these layers that of subsystems. Will help with integration later.

Participant: One of the areas that we haven't heard much about is the area of market design. As we look at market ops around the world (particularly US and Europe). These were designed without thought for zero marginal cost generation, and DR. One of the problems we are seeing with this 1st generation design is the problem with capacity adequacy, leading to evolving capacity markets. Perhaps it is worth taking a fresh look at market designs that include the new resources more explicitly or effectively?

Sauer: Not sure how many of the white papers are going to talk about the markets, but this is a good idea. Making gasoline from wind…not energy efficient, but if you have negative prices it might make sense.

Participant: We need to think about disruptive forces and anticipate what these might look like and what we might do about them. Either disruptive policy, or technology, or both.

McCalley: There is a possibility that some of the white papers might have time to include some of these perspectives in them.

Participant: We need to clearly defined objectives and constraints of what we need to do. Is the priority a zero-carbon society, economics, and reliability? Can't optimize all of these. How do we juggle all these? We need to define clearly what the drivers will be to architect the system because outcomes will be very different.

McCalley: White paper in high capacity interconnections/transmission (national overlay) probably captures more the idea of what we want to do. The national overlay might be unnecessary. Only certain regions might need it. Something like microgrids at the transmission level? It will pay us to look at the spectrum of possibilities and identify the merits and demerits of each perspective.

Sauer: We have optimization people here and we can do multi-objective optimization, but we need to prioritize these objectives. We won't be able to answer the optimization question in the white papers, but will try to define the problem as well as we can. There is also the issue of competing regulations, if you regulate one pollutant, might increase the other, etc.

Participant: From a decision theory point of view, we can combine the pareto multi-objective function to address all of the priorities. The technology is not there to do it all now, but can optimize with what we have and move forward. These will likely be suboptimal in each individual dimension, but optimal combination based on the priorities defined

Participant: Distributed systems with more localized resources vs. more national high cap transmission system. You could have highly interconnected system, but thing that haunts us the most is the high level of synchronicity that is required to make this work. White papers might include a vision of the grid with storage or power electronics to somehow reduce the synchronization requirement, so we get the benefits of interconnection without the burden of synchronicity.

McCalley: In transmission white paper, we will look at the competing economics, and non-economic benefits of different alternatives.

Closing Session Discussion (4:30 – 5:30 pm)

Vision, Scenarios, Future Grid

1. There is a need for a credible future state vision. How can a future vision be created? Otherwise, we end up with stranded investments along the way.
2. What scenarios, technologies, etc. are credible for planning purposes over a given planning horizon such as 10 to 15 years? There are so many possible future states.
3. We don't know what the new building blocks should be without credible paths/vision going forward. Need to identify a credible scenarios for planning and vision development. Need a credible scenario for the communications infrastructure, the IP infrastructure, etc.
4. Look for common elements among possible future scenarios. What's the probability of occurrence of the different scenarios?
5. Where are we going and how do we get there? Regulatory requirements end up fashioning a vision, but will the requirements change before we get there? How much investment should be made? What do we need to build to get to where we need to go? We just don't know where we are going.
6. Lots of confusion and uncertainty about the future.
7. Practical decisions need to be made. How do we do that?
8. Need a vision. What is the energy supply vision? Nuclear? Shale oil? Renewables? Geothermal?
9. Without a vision, the industry is put into a reactive mode. Just react to the policies.
10. Need an National Energy Policy
11. Vision: this is not just an academic issue. Developing it needs the involvement of industry, academia, government, etc. Academia has education responsibility
12. To do a vision, need assumptions, such as what the penetration of renewables will be in 2030?
13. To reach a vision, need to "stay the course" from a policy perspective. The vision will be driven by policy decisions.
14. Do we need to begin with and a vision about quality of life, national objectives, societal needs? What is the time-frame for the envisioned future/smart grid?
15. Need long-lived, consistent, high-level energy policy
16. Issue: life expectancies of new generation

System Development, Planning Approaches

1. Uncertainty grows the further forward you look. Alternative: build a robust grid that enables alternative visions. Long-term – not something an engineer can plan for.
2. Alternative: Start with a 100 year design rather than building for a 10 year plan. But make decisions for next 5 – 10 years predicated on the 100 year path. Design on the best information you have, and make the design "roll". The final result will end up being different than if decisions are just made based on what we are confident in today.
3. Would be nice if we were able to get everyone to agree - gov't, consumers, ... - which would then mean that moving forward, investing in smart grid, would be straightforward. Alternative: to design the systems and subsystems on an as-needed basis.
4. Need to plan assuming a learning process along the way. Renewables brings more uncertainty. Current design has been based on preventive strategies. Consider preventive versus correction strategies. What will we do if a particular scenario actually occurs. Plans need to be for responding quickly. Too expensive to build to prevent all bad consequences.
5. We overbuild in certain areas.
6. How much flexibility is possible in transmission planning?

7. What does the selected planning approach bode for the need planning tool needs/creation?
8. If we were start over with the grid, what would we do differently? Would this help us understand the future vision, say with storage?

Game Changers

1. energy storage
2. demand response
3. cheap post-silicon devices
4. new energy resource drilling technologies (e.g., natural gas). Now low-price natural gas is a significant driver of decisions today. Need to think of what is happening outside our industry.
5. improved gas-fired generation technology with much more flexible gas generators – can help renewables operationally in the system
6. cheap solar
7. carbon capture and storage (coal and natural gas)
8. demand intelligence/response with high penetrations of renewables
9. climate change
10. policy changes (e.g., removing subsidies, carbon pricing, etc.). Note: not charging for the cost of carbon emissions is a subsidy.
11. DC technologies in general (transmission, distribution, home, etc.)
12. EV's (what's the real viability? are they practical with regard to the needed infrastructure?)
13. order of magnitude reduction in the cost of batteries – will change the EV paradigm
14. new regulatory policies and business models promoting innovation
15. rare earth elements: not present in the US in large quantities. Availability? Cost? Risk?
16. ultra efficiency appliances
17. financial security management (e.g., collapse in value of euro)
18. fusion technology
19. advanced insulation and conductor technologies
20. use of nano-technologies
21. high-temperature superconductivity
22. room-temperature superconductivity
23. cyber warfare
24. changing education paradigms (use of electronic media)
25. more conservation