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Electricity Advisory Committee Meeting

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Summary of Meeting

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Ethics Briefing

Brian Plesser provided an ethics briefing for Special Government Employees and representative members of the Electricity Advisory Committee.

Welcome, Introductions, Developments since the June 2017 Meeting

Mr. John Adams, Acting Chair of the Electricity Advisory Committee (EAC or Committee), welcomed all attendees and thanked Ms. Pam Silberstein for coordinating with NRECA to allow the Committee's use of the space. Mr. Adams then invited the EAC members and Department of Energy staff to introduce themselves.

Update on the DOE Office of Electricity Delivery and Energy Reliability (OE) Programs and Initiatives

Deputy Assistant Secretary Katie Jereza thanked all Members for joining the Meeting. Ms. Jereza also welcomed the new members, noting that Michael Heyeck would be the new EAC Chair once he has been sworn in. Ms. Jereza gave a brief overview of her background. She also discussed the recent hurricane response operations, which included the standing up of the Emergency Response Organization (ERO), the Emergency Response Coordination Center (ERCC), the Regional Response Coordination Center (RRCC), and other ERO activities both in Washington D.C. and across local response areas. Ms. Jereza specifically mentioned the use of EAGLE-I, noting the ERO was shifting from Harvey restoration to Irma response. Ms. Jereza also mentioned that the ERO was monitoring the situation and supporting coordination between federal, state and industry partners, including other federal agencies like the U.S. Environmental Protection Agency (EPA) and the Federal Emergency Management Agency (FEMA) to conduct life-saving and life-sustaining activities, to mitigate fuel shortages, and to facilitate the restoration of electricity infrastructure. Ms. Jereza commended the unity of effort among stakeholders and also highlighted the Situation Reports being produced by DOE. She also reiterated that efforts are ongoing to build a more reliable, resilient and secure grid.

Ms. Jereza recognized awards of up to $50 million to be used to support early-stage research and development into tools and technology that can support next-generation electricity sector and oil and natural gas infrastructure. Awards have been issued as part of the Grid Modernization Initiative (GMI), made through the Grid Modernization Laboratory Consortium (GMLC). Ms. Jereza noted that microgrid projects are included among those receiving awards. She also noted that, given high penetrations of clean distributed energy resources (DERs) and emerging grid technologies at the regional scale, the projects supported by GMI awards are intended to demonstrate technical and economic viability to key stakeholders who are responsible for investing in grid modernization projects. Ms. Jereza indicated that these technologies are expected to have broad applications.

In the area of advanced grid research and development, Ms. Jereza discussed a project that would support both resiliency and economic development. She explained that the Small Business Innovation Research (SBIR) and the Small Business Technology Transfer (STTR) programs are congressionally mandated efforts that allow federal agencies to assign a certain portion of their funding for small businesses. These businesses would retain rights to any technologies developed; she noted four businesses were assigned awards. These awards were granted to allow recipients either to develop solutions for visibility and rapid damage assessment, or to improve other methods for supporting recovery of energy infrastructure following a disruptive event like a hurricane. Ms. Jereza commented that all four companies will develop solutions that can improve the timeliness and accuracy of damage assessments, which in turn can improve situational awareness.

Ms. Jereza was asked by Mr. Adams to elaborate on how Members serving positions within the EAC Leadership are selected, including not only the Subcommittee Chairs, but also how the additional responsibilities included in the EAC Chair and Vice Chair positions are allocated. She gave a brief overview of the process.

Mr. Adams announced that signup sheets were available at the entry table outside of the meeting room and encouraged members to sign up for positions on these Subcommittees. Mr. Adams gave an overview of the agenda for both days of the meeting.

Presentation on National Academy of Sciences Grid Resiliency Report

Dr. Granger Morgan, the National Academy of Sciences Grid Resiliency Committee Chair, gave an overview of the report developed by the National Academy of Sciences. He said that this report, entitled "Enhancing the Resilience of the Nation's Electricity System," could be downloaded.

Dr. Morgan introduced the study – requested by Congress and the DOE – to identify technologies, policies and organizational strategies that could be used to increase the resilience and reliability of the U.S. electricity system.

Dr. Morgan began his presentation by discussing the basics of disruptions to the electricity system, most of which are brief and local. He reported that the National Academy of Sciences study was focused instead on long-term outages: why they happen, and what can be done both to prevent and to address these. To begin with, he noted that large outages are more common than might otherwise be expected – this is known as the "long tail" phenomenon. Beyond the definitional answer to "what is resiliency," Dr. Morgan suggested more work could be done to address grid resilience, beyond simply reliability. He outlined that the report was organized around a three-stage Resilience Cycle. These stages are (1) Prior to an Event, (2) During an Event, and (3) After an Event, with an overall fourth stage that consists of observing, learning and improving in all stages. Dr. Morgan provided a more outline-focused organization of the report.

Beginning with Chapter 1, on Innovation and Motivation, Dr. Morgan quickly reviewed the basic assumptions of the report, including the criticality and ever-presence of interconnected and readily-available electricity delivery services. For at least the next several decades, the study assumed that a highly interconnected and tightly organized grid would be the status quo. Chapter 2, largely written by former EAC Chair Susan Tierney, discussed today's grid and the evolving system of the future. Dr. Morgan highlighted metrics for reliability as well as the potential to develop metrics that could communicate measures of a system's resilience. Dr. Morgan added that developing metrics for resilience is extremely challenging because it involves assessing how well the system is prepared for – or could deal with – very rare events, some of which have never happened. The National Academy of Sciences report recommends that DOE work on improved studies to assess the value to customers of full and partial service during long outages, as a function of key circumstances. Dr. Morgan also shared that the report calls for a coordinated response capability. Dr. Morgan added that Chapter 2 discusses Future Change for the grid in a scenario structure, which recognizes various bulk power system infrastructure and regulatory evolutions that could take place. The report intentionally did not attempt to pick which scenarios would be most likely, but rather outlined a range of what could happen.

Dr. Morgan proceed to the four main chapters of the report, beginning with Chapter 3, which discusses the many causes of grid failure. Some are physically induced – like attacks or operator errors – while others are induced by conditions in the natural environment, he shared. The report outlines that warning and restoration times vary greatly for different threats. Dr. Morgan noted that these warnings can also vary by geography or grid component use, like that of seismic readings or telemetry. Chapter 4 outlines strategies to prepare for and mitigate large-area, long-duration blackouts. Most recommendations are directed to specific entities and these are organized by entity at the end of Chapter 7. At least twenty are directed to DOE, as Dr. Morgan relayed. Returning to Chapter 4, Dr. Morgan outlined several technological opportunities to enhance system resilience, highlighting the notion that critical facilities could be powered-down given any notice that a disruptive event may be imminent. His overview of other recent discussions included the need for better monitoring and reporting technologies to support visibility along all levels of the electricity system. Cyber resiliency as a topic was also discussed in the report – as opposed to cybersecurity – because the National Academy of Sciences determined that their definition of resilience was not that a system was designed to keep bad actors out, but instead that black start and other recovery capabilities could be enabled in the aftermath of a substantial outage event. Dr. Morgan added that tools and technologies could include improving modeling capabilities or large-scale grid simulations.

In discussing Chapter 5, Dr. Morgan covered several strategies for reducing the harmful consequences from loss of grid power, suggested that testing and other requirements be considered, and suggested that fuel-electric interdependencies could be supported by testing generators and ensuring reliable fuel delivery contingency plans, among other actions. In addition, the study concluded that more work needs to be done on advanced preparations for the use of non-traditional sources of backup, like trains and ships; cruise ships could be incredibly powerful mobile generators. In addition, aside from sorting out regulatory and safety issues, DERs – like solar photovoltaic panels and home batteries – should be able to stay in operation while the grid is down. Other forms of mobile capacity could include electric vehicles, though such use currently could void the warranties of these electric vehicles. Overall, while there have been a variety of studies on the value of electric power, most of these have been in the context of short outages; Dr. Morgan continued by suggesting that society has not explored willingness to pay for – and value derived from – full or partial back-up service during large outages of long duration. He added that some work is already being done in these areas by individuals, but a more centralized, concerted effort could be useful and that making the "smart grid" a reality would require more work either supporting expanded reliance on microgrids or developing more reactive electricity capabilities.

Dr. Morgan continued by sharing that Chapter 6 discusses assessing, at each level across the system, how to restore major grid function following disruptions. This chapter includes key steps in restoration, from the planning and preparation stages through event management, infrastructure endurance, and finally restoration and recovery stages. Dr. Morgan highlighted a couple of key recommendations from Chapter 6 that focus on enhancing recovery. First, he suggested that the study concluded that the idea of a strategic transformer reserve is worthwhile, with more research needed. Second, he commented on the related efforts by DOE around building large transformers with substantial solid-state capabilities.

Dr. Morgan finally discussed overarching recommendations. The first recommendation was that operators of the electricity system should conduct more regional emergency preparedness exercises that simulate accidental failures, physical and cyber attacks, and other impairments that result in large-scale loss of power or impact other critical infrastructure sectors.

The second overarching recommendation was to take advantage of implementing available technologies and best practices in the field of grid modernization research. Dr. Morgan noted that the report also discusses strategies – outside of rate-basing – that could be leveraged to finance solutions that support broad resiliency and social good. The third overarching recommendation Dr. Morgan caveated, reminding attendees that the National Academy of Sciences cannot tell any agency how to spend its money. Broadly, however, the report reiterates that DOE-supported research is critical. Fourth, the study recommends that through public and private means, the U.S. should support investment in physical and cyber infrastructure components. Final recommendations shared by Dr. Morgan include that DOE and the U.S. Department of Homeland Security (DHS) should jointly establish and support a "visioning" process that can systematically imagine and assess plausible large-scale grid failures. In addition, the report concludes that stakeholder collaboration across the board is crucial; for example, the National Association of Regulatory Utility Commissioners (NARUC) and the National Association of State Energy Officials (NASEO) could form a strategic alliance to guide the decision-making of state regulators.

EAC Discussion of National Academy of Sciences Report Conclusions

Ms. Laney Brown asked Dr. Morgan to revisit his slide indicating that large-scale outages are larger than we think. She prefaced her question by confirming the Customer Average Interruption Duration Index (CAIDI), System Average Interruption Duration Index (SAIDI), and System Average Interruption Frequency Index (SAIFI) do not include large-scale outages. Because these outages are so rare, Dr. Morgan answered that any metric developed may not be fully adequate. He also suggested that in the near term the most useful next step may be building better simulations for long-term outage events. Ms. Brown also asked about how to cover the costs of conducting cost-benefit analyses. Dr. Morgan responded that in some contexts cost-benefit analyses may be useful, but that a lot of the issues related to long-term electricity delivery outages are considered social costs, related to quality of life and the private sector's willingness to pay to avoid issues associated with outage events. He added that technological solutions can limit the fallout from outages to some extent as well. These include more efficiently using smart meters and other solutions. However, he suggested that regional vulnerability needs to be more realistically considered, with investments made according to scale. Ms. Brown added that, in her experience, articulation of value is a core challenge, yet once it has been accomplished to some extent, investment priorities can be clarified.

Mr. Rolf Nordstrom thanked Dr. Morgan and asked two questions. First, he asked Dr. Morgan whether the National Academy of Sciences concluded that a joint priority of DOE and DHS should be to support broad-scale security. Dr. Morgan replied that since DOE and DHS do not operated the wholesale power system – the bulk power system – they can do demonstrations and make recommendations, like showing what certain actions would cost, but that operators, state public utility commissions, or municipalities would need to be the entities to take concrete actions. Mr. Nordstrom followed up by asking whether the National Academy of Sciences report makes any suggestion at all regarding which entity should take a lead. Dr. Morgan answered that the report does not make this type of recommendation, since the committee felt unable to do so. Mr. Nordstrom finally asked whether, given the number of baseload plants due to retire in the near future, the National Academy of Sciences report had made any recommendations to take advantage of any natural infrastructure turnover opportunity to make sure the system is made as resilient as possible. Dr. Morgan pointed to the end of Chapter 2 for discussion of factors that could enhance or exacerbate the resilience of the system, but acknowledged the report had not made specific recommendations.

Dr. Mladen Kezunovic shared several comments. First, he commented that the issue of resiliency would not reside in any single EAC Subcommittee. Second, regarding the scope of resiliency, Dr. Kezunovic cited statistics available that suggest catastrophic events account for 7-9% of total outage duration, with the remainder of outages being of the everyday variety. He added that expanding the scope of resilience activities beyond response then would include practices down to the everyday, e.g., maintenance and protection practices. Overall, Dr. Kezunovic asked whether industry workers need to go back to evaluating everyday practices. Dr. Kezunovic's final comment was that he supported the ideas that utilities are the entities primarily responsible for addressing resilience, but that the responsibility should be delegated by utilities.

Mr. Adams asked Dr. Morgan to return to the graphic he provided, plotting several recent major electricity delivery system outages along a curve of the scale of outages expected. Dr. Morgan explained that the dashed curves entailed fitting a curve to the more common events, and then extrapolating out to the larger events. He added that the curve demonstrates that the larger events are more common than one might guess, if one were only extrapolating from the more common causes of short-term outages, like squirrels, etc. Mr. Adams asked for more detail regarding specific actions that could be taken to mitigate the impacts of these long-term outages. Dr. Morgan directed him to the back half of Chapter 7, beginning on page 77.

Representative Jeff Morris commented that, based on institutional memory, one of the top recommendations from the 2003 Cascade exercise was to develop and implement better practices around credentialing, but that fourteen years later this remains an issue. Rep. Morris first asked whether, given the work that Alberta has done in which they conducted a province-wide assessment by the military on cascading power failures, participation by the military had been considered by the National Academy of Sciences. Second, Rep. Morris shared that industry partners in Washington had communicated their interests in having greater cyber network monitoring such that exercise traffic could be effectively distinguished from other outside actors' penetrations. Regarding the first question, Dr. Morgan said the report includes discussion of better modeling capability and more realistic data sets needed to work the problem described. He suggested that the second question should be directed to Bill Sanders of the University of Illinois or Craig Miller at the National Association of Rural Electric Cooperatives (NRECA). Ms. Brown asked a follow-up question about technology best practices: are they easily attainable, or are there steps that need to be taken to enable collection or development of these practices. Dr. Morgan replied that the answer varies, which is why the report recommends demonstration activities.

Mr. Clark Gellings offered a warning regarding copyright protections on the report; Dr. Morgan said he could arrange for permission to reproduce and circulate the report. Mr. Gellings also commented on the relationship between loss of load probability and willingness-to-pay. As a former public utility commissioner in New York, he noted that willingness to pay changes dramatically after stakeholders have experienced an event like Sandy. Mr. Gellings also commented that certain types of hardening – like line undergrounding – does not solve all problems. Back on the issue of willingness to pay, Dr. Morgan referenced Lawrence Berkeley National Lab's (LBNL) study summarizing willingness to pay estimates, noting that most evaluations were for a day or less.

Mr. Chris Shelton praised the structure of the report. Referencing slide nine, Mr. Shelton mentioned his appreciation of architectural considerations in Chapter 4, and asked whether there were other specific recommendations related to a clear role for DOE in evaluating system architectural considerations to reduce criticality of individual components. Mr. Shelton encouraged more thinking about architectural solutions that could respond to need created by retiring facilities and could be steel-in-the-ground components of greater future grid resiliency. Mr. Tom Weaver asked whether any further scoping would be conducted related to risks across a wide area, versus the more localized distribution issues that may currently dominate transmission contingency planning. He noted the many interdependencies between the transmission and distribution system architectures. Dr. Morgan responded, noting the importance of identifying specific issues and then identifying who should be responsible for addressing or fixing those.

<u>Panel Session: Modern Grid-networked Measurement and Monitoring</u>

Dr. Jeffrey Taft introduced the Modern Grid-networked Measurement and Monitoring Panelists, including: himself, Chief Architect for Electric Grid Transformation at Pacific Northwest National Lab (PNNL), Ms. Alison Silverstein, Project Manager at NASPI, Mr. David Pinney, Analytics Research Program Manager at NRECA, and Mr. Kyle Thomas, Supervisor of Transmission Operations Engineering at Dominion. Mr. Thomas was unable to attend the meeting due to ongoing hurricane recovery efforts in the Southeast U.S., and Ms. Silverstein provided his presentation on his behalf.

Dr. Taft led the panel by providing background on sensing, which transforms system status into an electrical signal that can be recorded and controlled. He began by sharing that smart sensors include a communications interface, from which data can be gathered and streamed to a control center. However, he said that sensing is not the essence of grid-networked monitoring and measurement. Instead, this structure uses grid sensors networked together. Broadly, Dr. Taft commented that sensor use is common in other fields like sonar, geophysical exploration, etc. In petroleum engineering, for example, these networks of sensors are used to measure and define what is called the system state. In the bulk energy system, state estimation refers to the power state of voltage and status. Dr. Taft shared that monitoring and measurement may be central or distributed, and may also be considered virtual sensing, which uses a combination of sensors that together give an understanding of the aspect of system state that one wants to know. He noted that Alison Silverstein would present on rate processing; since Kyle Thomas was not able to make it, Ms. Silverstein will also give his presentation. He also shared that David Pinney of NRECA would talk about SCADA, and that he himself would conclude by talking about architectural considerations more broadly.

Ms. Alison Silverstein led off the panel presentations by discussing how synchrophasor technology improves grid reliability: it is 100x faster than Supervisory Control and Data Acquisition (SCADA), it is time synchronized, and it is capable of identifying failing equipment and other unexpected grid conditions that enable response. She added that synchrophasor technology also provides the capability for grid operators to create redundant systems based on synchrophasor technology-enabled modeling of system states. To begin her presentation, Ms. Silverstein showed a slide that compared the grid visibility received from synchrophasor use to that achieved from the use of SCADA systems. She contended that the Phasor Measurement Unit (PMU) reflects reality, while the SCADA measurement is better at identifying 4-second history than predicting grid trends forward. She added that elements of synchrophasor technology – once PMUs are placed at key substations and generators – demand several cooperative grid components. These include: fast, secure, and reliable communications networks; high quality applications and analytical tools; the use of technical interoperability standards; and utility and vendor business practices that support reliable systems. Ms. Silverstein stated that the North American SynchroPhasor Initiative (NASPI) is partially funded by DOE, with support from the North American Electric Reliability Corporation (NERC), the Electric Power Research Initiative (EPRI) and several utilities. She characterized the research into synchrophasor technology as building a railroad track with the train immediately behind, stating that a key challenge that remains is how to figure out how to implement grid components while simultaneously addressing interoperability standards and fixing business practices to facilitate the deployment of interoperable PMUs and their real-world use.

Giving a brief overview of the technical process of component communication, Ms. Silverstein shared that PMU data is fed into a phasor data concentrator, which in turn is fed into a corporate phasor data concentrator, which finally siphons off data either to analyze, to send to Regional Transmission Operators or Independent System Operators (RTO/ ISOs), or to develop other simulations or tests. Ms. Silverstein commented that approximately 80 networked PMUs were in service across North America as of 2007, with these sensors mostly located in the Bonneville Power Administration (BPA) service territory, with others in the territory served by American Electric Power (AEP) and still others clustered around the University of Virginia and the PJM Interconnection bulk power system. She indicated that the Southwest Power Pool (SPP) was starting to expand their sensor penetration, and the Electric Reliability Corporation of Texas (ERCOT) maintains a leading position in the field. In addition, Ms. Silverstein suggested that Florida has been proactive about shipping data up, but that likely many of their PMUs were impacted by the recent Hurricane Irma. Returning to SPP, Ms. Silverstein introduced them as a great example of how utilities and power marketing administrations (PMAs) are seeing so much value from PMUs that they are incorporating them into all new substations, rather than making sensor deployment contingent on federal grant incentives.

Ms. Silverstein outlined several uses currently possible for synchrophasor technology. First, synchrophasor data can improve situational awareness and off-line analysis of the functionality of the bulk power system. Ms. Silverstein commented that if phase angle monitoring and voltage stability monitoring had been possible in 2003, the great Northeastern blackout could have been avoided. Regarding the operational landscape, Ms. Silverstein said that the capabilities of synchrophasor technology are embedded in several key NERC standards today. Other areas of research supported by synchrophasor technology include forensic analysis, as well as the steady state identification of equipment problems and mis-operations. Regarding forensic analysis, Ms. Silverstein commented that the only sensor data available in 2003 was provided by the DFR sensors located at hydroelectric facilities in Ontario, but that PMUs can be used more now than they were then. Regarding general system monitoring and cybersecurity, Ms. Silverstein asserted that utilities and grid operators should be using PMU data as a matter of course now to verify that system protection operations are functional.

Turning to a section of the presentation focused on "A bad day in the western interconnection," Ms. Silverstein animated for the group an event replay of the September 8, 2011 Southwest blackout, which was captured not by PMU data, but by Frequency Monitoring Network (FNET) data, which are designed to be similar. She commented that while PMU data are superior, the eighty-odd PMU owners are less generous with the data collected. Returning to the Southwest blackout, Ms. Silverstein introduced the BPA's oscillation detection tool. She compared the tool with the wind farm oscillations discovered in ERCOT as a result of PMU data. These included both frequency and voltage oscillations. She remarked that sustained oscillations are capable of damaging equipment and could even compromise system security. An event in ERCOT, for example, lasted nearly 36 hours, which was a long time to put an owner's system or someone else's power plant at risk. Returning to BPA generator models to conclude, Ms. Silverstein explained how both the before-event and after-event readings can be validated by using real PMU data, since models exist both for active and reactive power.

Ms. Silverstein also shared how PMUs can be used to monitor substation equipment. For example, Dominion has been known to use PMUs to monitor Capacitor Voltage Transformers (CCVTs). Dominion noticed from CCVT monitoring that the A & B phases were properly operating, but that the C phase was mis-operating. By using PMU measurements to monitor real-time grid infrastructure state and respond faster to abnormalities, either with immediate shutdown or a more optimized maintenance schedule, Ms. Silverstein offered several examples of solutions made possible by better data visibility. Other problems detectable with PMUs include generator setting and equipment failures: local phase imbalanced and other adverse transmission conditions; transmission equipment problems like failing transformers or loose connections; and the verification of the operational status of system protection devices.

Ms. Silverstein continued by listing several ways in which PMUs can be used to meet NERC reliability standards. In terms of the integration of renewables, PMUs support system modeling, oscillation mitigation, and transmission management. Regarding transmission, one solution she highlighted was dynamic line loading for greater throughput without more capital investment. In addition to steady state services like baselining and system protection operations monitoring, Ms. Silverstein also shared several ways in which PMUs can be deployed as a cybersecurity measure. These include capabilities ranging from the ability to monitor ground-induced current (from GMDs) and seismic event impacts, to the ability to trigger automated system protection operation, to the ability even to detect electrical islanding and facilitate blackout restoration using these resources, as was done around New Orleans following Hurricane Gustav.

In terms of what is next for synchrophasor technology, Ms. Silverstein suggested that coordination between sensing research and that of advanced machine learning would facilitate the development of automated, autonomous system protection schemes, including wide-area damping. In short, she suggested that sections of the grid could be self-adapting to dangerous grid conditions. Ms. Silverstein also mentioned several distribution-level uses for the technology, since there is value attached to synchronized, high-granularity measurements. On the distribution system, it is more difficult to differentiate signal from noise, but this is an area in which more sophisticated sensing can be useful. In general, Ms. Silverstein conveyed that the deployment of more advanced PMUs could also facilitate greater transparency between the transmission and distribution levels if data sharing is made possible across transmission operators and resistor-capacitor circuits. Ms. Silverstein asserted that while synchrophasor technology will continue to evolve, the next key advance will be solving issues associated with institutional isolation and a lack of data-sharing.

Ms. Silverstein next transitioned to a slide deck that had been prepared by Kyle Thomas, entitled "Synchrophasor Design, Deployment and Applications," since Mr. Thomas was unable to attend the EAC Meeting due to ongoing hurricane recovery efforts in the Southeast U.S. Mr. Thomas's presentation began by outlining new perspectives made possible by PMUs. His presentation listed several examples, one of which highlighted the ability of PMUs to detect classic power oscillations at a nuclear power plant, due to a three-phase fault near the nuclear power system. Ms. Silverstein continued by highlighting the RTDS Operator Training Simulator, capable of receiving PMU data and combining those signals with runtime controls and visualization software that makes it possible to train operators to respond in real time to realistic events fed into a simulator.

Regarding synchrophasor architecture at the substation level, Ms. Silverstein outlined how not enough data analysis had been done to date to be able to build effective, PMU-enabled support tools. However, several standards apply to synchrophasor and PMU deployment at the substation, she shared. Four standards in particular apply to grid-networked monitoring and measurement and govern both construction standards and business operational and infrastructure design. Future substation PMU standards are being scoped for non-Critical Infrastructure

Protection (CIP) PMUs and also for black start PMUs, she added. In the near future, Ms. Silverstein suggested that these standards would also apply to distribution substation architecture.

Referring back to the presentation, Ms. Silverstein updated the EAC that one DOE-funded project that Dominion Virginia Power was participating in was the Open ECA software. The objective of developing this software was to develop an open source software platform that facilitates the development of analytics that use high-fidelity synchrophasor data. Since Open ECA is an OSS platform, its development would allow other software to be "parked" on top of the bus in order to enable even higher-quality data gathering. Ms. Silverstein added that alpha tests are being conducted at Dominion and at Oklahoma Gas & Electric, while SPP had elected to beta test the software. Mr. Thomas's presentation suggested that the motivation for developing the platform is to allow analytics developers to focus on techniques and tools while lowering the costs of software and tool development for the industry and also allowing a smoother integration of third-party tools. The software provides various analytics itself as well, including oscillation detection, mode metering, and the use of PMU synchroscopes, which can be used to synchronize islanded generators with the grid. Regarding the concept of advanced angle measurements, Ms. Silverstein informed the group that cumulative delays can be calculated depending on network configuration and the traffic of the path adopted. In terms of implementation, she reiterated that Open ECA is open source. At the time of the meeting, it had been tested, deemed workable, and deemed capable of accomplishing what it is intended to accomplish. Going forward, Ms. Silverstein added that greater deployment of synchroscopes may be the next frontier, as a synchroscope is capable of synchronizing two buses from a remote location and could greater aid visibility on the bulk power system.

Dr. Taft commented in transition that several of the operations enabled by PMUs require the synchronization of several different PMUs in order to collect data across the same time step and then analyze the outputs. Dr. Taft next introduced Mr. Pinney, who began his presentation by giving an overview of the country's electric cooperatives. He commented that given their sparse customer base, cooperatives often favor grid sensors for a different reason than investor-owned utilities: sensors can help cooperatives avoid the lengthy travel necessary to perform on-site inspections of grid infrastructure. In terms of emerging grid requirements, Mr. Pinney commented that new technologies are needed to meet emerging grid challenges. He added that more space exists for advanced sensors to improve operator understanding of grid status.

In contrast to the previous two presentations, Mr. Pinney stated that the vast majority of distribution cooperatives favor AMI; 76% of all cooperative customers had a smart meter in 2013. He posited that the penetration could be nearing 100% now, four years later. Mr. Pinney also suggested that the majority of cooperatives use SCADA as well, with the majority of those meters served by power line communication (PLC) technology. Wireless radio frequency and fiber deployments are growing in popularity as well, while falling distributed PMU costs suggest further power quality monitoring opportunities exist. Overall, Mr. Pinney concluded that more can be done with data from the existing sensors, which is a more approachable solution for cash-strapped rural cooperatives than investing in the more expensive synchrophasor technology.

In order to deliver maximum value from sensor data, Mr. Pinney indicated that cooperatives are starting to see more applications at the interface of generating assets and the transmission and distribution systems. Specifically, sensors enable better load planning if various AMI data can be integrated between vertically integrated cooperatives and among transmission and distribution cooperatives. The Multispeak web services bus, for example, meets interoperability standards and can support more than a dozen end-use applications that utilities can use both for planning and for operations. For planning research, Mr. Pinney shared with the group the advantages of the open-modeling framework, built by cooperatives and DOE. The framework offers models to determine cost-benefit analysis as well as engineering models to enable the integration of multiple DERs, among other functions.

For planning purposes, AMI data can be used to support Volt-Var optimization. With SCADA or AMI data as inputs, Mr. Pinney shared, models like CYMBIST or Windmil – which can be converted automatically to open format – can be used to achieve peak demand and energy reductions that in turn can be converted to cost impacts. Another application where sensing and measurement can support planning is in facilitating the integration of solar resources. Mr. Pinney added that by using load and circuit models and the utility location – provided by NOAA – as inputs, sensor data can be used to detect overvoltage, reverse power flows, or other changes to voltage regulation. A third planning application he introduced was the ability to improve energy storage valuation. Inputs including load, circuit configurations and location data are provided, with the platform facilitating the output of calculated realistic storage dispatch, the impact of net load on cash flows, and the integrations of energy storage into a full quasi-static time series (QSTS) measurement. Mr. Pinney added that a final planning application for data was in determining the optimal investment in resilience. Adding damage maps (those of wind damage, water levels and earthquake shapes) into the standard inputs, NRECA was able to work with Los Alamos National Lab to build a fragility model to determine which parts of the circuit are most likely to be damaged. In addition, Mr. Pinney's team is working to develop an optimization model where – given a certain amount of money – the optimal deployment of those funds to improve the resilience of the system can be calculated. Related efforts include working with Pacific Northwest National Lab to determine which switching and control actions would be needed to achieve that new, optimal system.

Turning to operational considerations, Mr. Pinney listed several operational needs met by AMI. Firstly, he shared that meter-reading efficiencies typically recover the cost of AMI deployment, while a "long tail" of other applications can be added over time. Currently, he commented that integration costs are the largest barrier to additional applications. Mr. Pinney added that supporting operations research is GridState, a system developed to passively monitor and analyze a comprehensive range of data from and about utility electrical and control system operations. Initially funded by DOE and the Defense Advanced Research Projects Agency

(DARPA), the objective for GridState is to provide utilities and other stakeholders with total situational awareness. Further ahead, Mr. Pinney predicted that unification of grid planning and operations software between Open Modeling Framework (OMF) and GridState (used for distribution system operations) will allow for better cross-configuration and analysis of data to address general physics problems. In conclusion, Mr. Pinney shared that networked sensors are widely deployed at rural electric cooperatives, with their data integrated into multiple planning operations. Mr. Pinney also noted that NRECA looks forward to newer and improved network capabilities as backhaul bandwidth increases.

The final panelist, Dr. Taft, indicated he would conduct his presentation from an architectural perspective, with a focus on distribution in particular. He focused on a specific scenario: increasing the penetration of DERs into the grid, especially including the use of electricity generated from variable renewable energy sources. In the domain of DER problems, Dr. Taft suggested that architectural models focused on high penetrations of DER deployment are being driven by trends toward greater use of solar PV and microgrids, among other resources. Several trends result from these deployments. First, Mr. Taft explained that the integration of renewables changes how the grid is operated. Renewable integration creates fast dynamics at the distribution system level that creates balancing and stability issues to the grid, affecting voltage regulation and system stability. A second trend of grid development created by DER deployment is that more endpoints at the grid edge and less time for the system to react demands more and better data in order to coordinate operations. These endpoints not only impact sensing and control, but also affect independently reactive components responding to system states. In imagining the future distribution system, Dr. Taft projects the greatest need emerges at the generation and load tie point. By coordinating the two sides of the system and providing the network upon which responsive load and responsive generation can operate, grid-networked sensing and measurement creates the system visibility necessary to support a transactive energy environment.

Connectivity, especially via the internet, introduces cyber threats, Dr. Taft added. He suggested that this fact should impact how utilities and operators handle sensing and measurement at the distribution level. Although the preferred DER structure would be deployment within a single distribution operator's storage area, in the meantime all distribution system operators need to be focused on managing assets at the distribution level and coordinating those assets with developments at the transmission level. Dr. Taft asserted that distribution system operators ought to focus primarily on operational coordination even above overseeing distribution-level markets. Dr. Taft concluded that distribution system operators will need superb visibility on the distribution grid, both to support asset deployment and to enable greater coordination with transmission system operations.

Remarking on where the distribution systems stand now, Dr. Taft commented that many distribution systems have little or no SCADA and that many distribution system substations have no SCADA at all. He added that older AMI is not as useful for grid sensing, while newer technology is improved but not widely deployed. Given the limits of weak, siloed and non-converged communication networks for the distribution system, Dr. Taft stated that these failures of communication result in poor grid topology model accuracy, which is critical for data context. In his experience, utilities share that their connectivity models are only 50-80% accurate, but that those models are the context being used to interpret sensor data, which suggests they likely provide inadequate context. In addition, grid sensor installation is expensive. Dr. Taft provided a list of current distribution system sensor uses. Discussing the work with GMLC on a sensing and measurement strategy project, Dr. Taft outlined what instantaneous operating condition data is necessary to improve the operational efficiency of the distribution system. He added that several measurement issues remain on the distribution system, from a control system point of view, which makes more sense if the measurements are aligned in time (synchronized); from an instrumentation point of view, where real applications include fault detection and pre-fault detection; and from a data sharing point of view. Because applications are brittle, Dr. Taft shared that the ideal is figuring out how to change architecture so that systems are more resilient against point-source disruptions.

Discussing implications for modernized distribution system networked sensing and measurement, Dr. Taft reviewed electrical measurement and architecture issues. He remarked that one way to break up vertical silos is to decouple certain applications and stack them on a common platform, or to allow for distributed applications that are interoperable. With reference to networking, Dr. Taft praised redundancy and multicast streaming, while noting that sensor technology would also be crucial, especially if inexpensive installation becomes possible. In final comments, Dr. Taft commented that today's grid needs to be more visible than the twentieth century grid needed to be. Because of this, he added that sensing and networking devices ought to be considered core infrastructure. Based on his experience, Dr. Taft suggested it would be best to consider the best fit or least cost solutions enabled by modernized grids capable of supporting high DER penetration and advanced capabilities. Dr. Taft concluded and invited general discussion.

Discussion of Potential EAC Next Steps for Modern Grid-networked Measurement and Monitoring Topic

Mr. Adams thanked all of the panelists for their presentations and opened the floor for discussion. Dr. Kezunovic thanked the panelists and commented first on how synchrophasor technology could be adapted to support resiliency, and that it might be nice to pinpoint capabilities critical to resiliency so that the tech development can be benchmarked. Second, Dr. Kezunovic commented that the maturity of the technology is a need-to-know before the application of certain technologies to multiple end-uses or data leverage can be estimated by DOE or others. Dr. Kezunovic mentioned that he made similar comments at the National Institute of Standards and Technology (NIST). Lastly, he commented that there is a need for something that will coordinate the sensing technology that will allow grid technology to be tied into the most mature grid operating systems; in sum, he asked whether researchers are patching in new technologies or whether they are contemplating an entirely new system design. Dr. Kezunovic asked Dr. Taft whether he anticipates replacing Energy Management Systems (EMS) or Distribution Management Systems (DMS). Dr. Taft responded by highlighting the DOE-sponsored DSPx project, which begins to answer some of these questions about maturity and system configuration. Dr. Taft also acknowledged that GMI is not a greenfield solution, but requires a legacy-to-future transition with substantial costs that demand financing solutions and a roadmap.

Ms. Silverstein commented regarding the maturity that there is a distinct difference between the maturities of the technical idea versus the adoptable component. She referenced the six steps necessary for technology adoptions that were highlighted in her presentation. Replying to questions around the application of synchrophasor technology to resiliency, Ms. Silverstein made two suggestions. First, she suggested there is the use of the technology for making the grid more nimble, but there are also methods being developed for the system to be more responsive to unexpected grid states. She also commented that the industry as a whole should be investing more in energy efficiency and solar, not just conducting hardening activities but improving customers' abilities to survive outage scenarios. Ms. Silverstein summarized the charge as that to "design graceful failure." Mr. Pinney commented regarding the question of technology maturity that even though engineers would prefer the perfect DMS system be in place, technology is progressing too fast for that vision.

Dr. Morgan asked Dr. Taft how researchers and operators conduct state estimation, given that the actual current state of the grid system is necessarily presented on a delayed basis according to the amount of time data aggregation and communication takes. Dr. Taft replied that the delays are not ideal, but that the timestamps allow for the aggregation of data to match time-aligned data. Since control theory deals with latency in measurements, he added that it is known how to understand the dynamic if there is latency in the system. However, he cautioned that too much latency can cripple feedback control. That said, Dr. Taft asserted that system limits are not often the problem, but instead the key is to compensate for known latency within the system limits by implementing different types of control compensation. He added that industry currently has the capability for high-speed networking to coordinate low-latency data.

Ms. Silverstein concurred that networks are significantly faster today than previously and that engineers are finding better ways to compensate for latency. However, she noted that redundant PMUs that have visibility over overlapping service areas can allow for greater visibility across PMU data outputs. Ms. Silverstein also added that she is working on probing the vulnerability of assets: specifically, how many PMUs need to be lost or how late does the data need to be in order to erode the quality of the data or its trustworthiness as applied. Mr. Pinney added that in theory or in models, these grid-networked systems work perfectly. However, he raised alternating current optimal power flow issues as one example of how real-world application (and visibility) differs from that of the model. He added that a major research challenge is how to continually update the rules for control in such a way that they do no rely on human judgment.

Mr. Nordstrom thanked panelists and asked what the implications for distribution system planning would be, given wider deployment of grid-networked sensors. Dr. Taft referred back to the DSPx project. The final product became three volumes, one of which has an entire section on distribution planning, not only analyzing capabilities and failings of existing distribution system planning tools, but also outlining gaps. Mr. Pinney added that most coops use the WindMil platform, both for voltage control and system visibility. He commented that other research tools allow for other modeling capabilities, given that you have the human software capacity. Ms. Silverstein suggested that research should be focused in two areas to support grid planning: detailed load research and big data analysis of the system state. She added that research should also be focused on developing self-announcing grid state tools, where changes in system state trigger a signal (LED or other). When LEDs, electric vehicles, PV inverters and other efficient, variable-speed motors are combined, she proposed that existing models for load behavior can no longer be considered credible. Mr. Pinney agreed and commented that based on his experience helping distribution cooperatives refine their models, more attention needs to be paid to load disaggregation and the related use of load detection algorithms, as well as efforts to improve SCADA.

Referring back to Mr. Adams' question about what the EAC should be doing for DOE, Ms. Silverstein replied that the EAC should lay down markers for collecting and sharing data for the purpose of researching load behavior, conducting big data analysis on PMUs, and achieving other capabilities unlocked by sharing. Mr. Adams asked the EAC Members if they could offer next steps.

Dr. Kezunovic commented that resilience and future generations of technology are at the heart of the issue. He in turn asked how the issues are linked: can next-generation technology be used to support resiliency? Along the same lines, he added that the behavior of an IOU under FERC and NERC may vary from the behavior of utilities not under the same levels of federal oversight. One final challenge that addresses several problems is how to develop data-based models that are more accurate. In addition, Dr. Kezunovic suggested that data-based models ought to be leveraged to improve resilience. He also asked the panelists to comment on what DOE should do to incentivize or otherwise support industry efforts to improve the products already on the market.

Mr. Shelton asked, regarding Ms. Silverstein's introduction of machine-learning capability issues to the discussion, what should be done in order to develop a better sensory-motor type model for the system, which could not otherwise be created without synchrophasor technology granular data. Mr. Shelton asked about the feasibility of building a neural-based model with intra-model self-awareness that can produce better planning outcomes and better dispatch/ control outcomes.

Ms. Brown asked the panelists where they see areas of need or barriers to filling those needs, both in the near term and over the longer term. Dr. Taft answered that he is seeing examples at the distribution level of how sensing communications as a layer of grid architecture are impacting how the investments get financed. Ms. Silverstein suggested the EAC consider interoperability and resilience. She gave the example that the process of recovering from a disaster is inherently anti-interoperability in its current form. Since mutual assistance crews bring their own supplies and replace damaged grid systems with a variety of components, system interoperability – and even long-term repairs – are made more difficult by these quick fixes. Since retrofitting is time- and fund-intensive, industry-wide standardization of components (down to bolts) and procedures would be useful since common practices and equipment goals could support overall interoperability of the bulk power system. Mr. Pinney listed several additional conditions required to get the most value out of sensor networks. These include both hardware and software interoperability, having the bandwidth to get data off of meters, general data integrity, maintaining cybersecurity by using trusted tools and processes to secure data on sensor networks, and having applications available to make use of sensor data, like ongoing machine learning applications.

Mr. Weaver suggested that PMUs and synchrophasor technology on the transmission level are more advanced than sensors on the distribution system. He also stated that more action needs to be taken to resolve the ownership and sharing of data to prevent needing to scrape data from sensor operators. Regarding planning, Mr. Weaver suggested that a need exists to consider grid devices not currently involved in planning. He gave the example of greater visibility into how DERs are operating. If they are net-metered, sensors currently do not even show detailed generation data. Mr. Weaver said that there is a need for metered information on the production of those DERs and which DERs are reacting to system conditions, on top of simply how many Watts of production remain, net of demand.

Mr. Adams issued a final thank you to the panelists.

Wrap-up and Adjourn Day 1 of September 2017 Meeting of the EAC

Mr. Adams invited final comments of the day from the EAC Members. Hearing none, he adjourned Day 1 of the meeting.

Respectfully Submitted and Certified as Accurate,

John Adams
ERCOT
Acting Chair
DOE Electricity Advisory Committee

02/20/2018
Date

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