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Electricity Advisory Committee Meeting

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Meeting Summary

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Panel: Frequency Response and Grid Resilience

David Ortiz, Federal Energy Regulatory Commission (FERC), explained that the panel discussion is organized around a study for FERC on frequency response, and that there has been a lot of interest on a changing generation fleet. The concerns around inertia are around frequency response. The industry has been managing frequency response for a long time, which refers to how the power system prepares for and endures the loss of a large generator. This panel will discuss some of the core activities around frequency response.

Dr. Ortiz said that FERC has the authority to consider the reliability of the bulk power system and does so through its oversight of the North American Electric Reliability Corporation (NERC), which develops and implements standards subject to the Commission's approval. Dr. Ortiz's office, the Office of Electric Reliability, works closely with the Office of Energy Market Regulation to ensure that market regulations maintain system reliability. In 2013, NERC emphasized long-term reliability assessment with concerns involving the changing resource mix. FERC issued a notice of inquiry asking whether to change to generator interconnection agreements. A final rule was issued that specified that all newly interconnecting small and large generators are required to provide frequency response. The Order exempted combined heat and power. It also did not mandate compensation for primary frequency response. FERC asked Lawrence Berkeley National Laboratory (LBNL) to update a 2010 study on primary frequency response, which identified primary frequency response as a critical issue. However, given the changes to the grid and projected changes, FERC thought it made sense for the study to be updated with new modeling and provide more insight on the specifics.

Dr. Ortiz introduced Joe Eto, LNBL, who provided an overview of his study. He described the objectives for the study and the conclusions made. He began by introducing frequency response concepts and the basic terminology. LBNL conducted a study in 2010 and the concern was with the increasing penetration of renewables and the impact on system reliability. The updated study expands on this to focus on managing frequency response overall and outlining the fundamental principles for reliability.

The main finding is that frequency response is an essential reliability service. The requirement for frequency response is met by the action of turbine governors. There are two elements to ensure there is adequate frequency response: 1) generation interconnection policies, and 2) generation dispatch policies.

Mr. Eto then reviewed the recommendations from the study. There needs to be focused attention on the collection, maintenance, and validation of operating data and study models. Different countries have different approaches to managing frequency response, so it would be instructive to examine other interconnections. There are also lots of emerging non-traditional resources, such as energy storage and demand response, which mean increased opportunities that should be examined. Finally, load is a frequency response performer that has the capabilities to automatically stabilize frequency, and should be examined in greater detail.

Frequency is a reflection of the balance between generation and load. When there is too much generation, frequency rises; when there is a loss of generation, frequency falls. When a large generator is lost, frequency falls very fast, so the key is to restore it before it goes to dangerous levels. One of the first danger levels is interconnection-wide under-frequency load-shedding. This involves shedding thousands of megawatts of load on an unannounced basis in an effort to forestall the drop in frequency. This is done to avoid turbine damage if frequency falls even further.

During an event, the change of frequency can only be arrested by rapid actions of primary frequency control resources. Once frequency is stabilized, the state is called the frequency nadir. For a given loss of generation, frequency will fall faster on a system with lower inertia. One way to think about inertia is how fast frequency will fall when you lose a generator of a given size. The rate at which system frequency declines is also determined by the size of the generation loss event. Frequency falls faster under the event of a greater loss of generation. These fundamental principles are critical for understanding primary frequency response. Both factors, inertia and size of generation loss, need to be considered together. How fast frequency falls will determine how fast frequency response controls need to operate.

If a system with primarily coal and gas is replaced by a system with primarily combined cycle, the system inertia will increase. A system with more renewables will decrease inertia. Mr. Eto explained that it is important to examine generation loss design events. In Texas, for example, a generation loss event makes up a higher percentage of minimum load. Thus, the Electric Reliability Council of Texas (ERCOT) has been very focused on the requirements for frequency response. The magnitude of generation loss event dramatically overwhelms the changes in system inertia. Therefore, it is important to also consider inertia in the context of the generation

loss event.

Mr. Eto provided a brief introduction to the methods used in the study. Researchers used the industry standard simulation tool, GE PSLF, and conducted thousands of runs. The first finding is that frequency is arrested when the amount of power that is injected from the primary control resources equals the size of the generation loss. Thus, the reserves must be at least equal to the amount of generation that is expected to be lost. The second finding showed that one generation unit, acting alone, would only rarely be capable of providing all the frequency response needed in the time available to arrest frequency. Multiple units are needed to contribute quickly. The third finding is that for a given loss of generation and system inertia, the speed with which primary frequency response is delivered determines when frequency is arrested. For the fourth finding, Mr. Eto noted the importance of sustained primary frequency response. One of the reasons that frequency response might not be sustained is due to actions of the plant load controllers. This finding is addressed in the fifth finding. Thus, the first recommendation is to add a frequency bias to plant load controllers, which is also the sixth finding. These six findings are the primary conclusions from the study.

The seventh finding is that gas turbines may not be able to sustain primary frequency response following large loss-of-generation events, and the eighth finding is that "synthetic inertia" controls on electronically coupled wind generation appear not to sustain primary frequency response. The ninth finding indicates the importance of fast demand response. In Texas, half of their rapid response service comes from load. They pay the load to be ready to trip when needed, which allows for rebalancing of the system. Batteries, and wind and solar (provided they have head room and operating governor-like controls) are great forms of frequency response. A deadband is a frequency deviation around a governor control where it does not operate. The tenth finding is that smaller deadbands on turbine-governors increase how quickly delivery of primary frequency response will begin. The eleventh finding is that load sensitivity currently complements primary frequency response, but this sensitivity may be going away. There are two cross-cutting recommendations. The first is to better understand issues around frequency response. The second is to review various practices both domestically and internationally.

Mr. Eto introduced the second panelist, Sandip Sharma, ERCOT. Mr. Sharma began by briefly introducing ERCOT. Texas is small compared to the Western and Eastern interconnections. Highest peak load was 71,110 MW. ERCOT has about 22 GW of wind and the instantaneous output was about 17,541 MW. Approximately 54% of load is served by wind.

Mladen Kezunovic suggested identifying the reasons for these events occurring and the contingencies. Mr. Eto said that generators go offline on a routine basis, which indicates the need for frequency response. Smaller events happen on a weekly basis, but very large events are quite rare.

Mr. Sharma continued that Texas is experiencing rapid changes in their resource mix. There has been an increase in combined cycle and wind. Solar is also expected to grow more than wind in the next year. Combined cycle is highly flexible, which is helpful for renewables. John Adams asked if all of this generation is grid-connected. Mr. Sharma clarified it is all transmission-connected.

The definition of resilience is the ability to withstand and reduce the magnitude and/or duration of disruptive events, which includes the capability to anticipate, absorb, adapt to, and/or rapidly recover from such an event. The definition of primary frequency response is the immediate (without intentional delay) proportional increase or decrease in real power output provided by resources (generators, energy storage, load and others). This proportional response is in the direction that stabilizes frequency. Primary frequency control comes from actions of local control systems. Mr. Sharma discussed an example of a frequency event in ERCOT, which happened a few months ago, where they lost 1,250 MW. At the time, load was about 40,000 MW. System frequency declined rapidly due to the loss, but was recovered in less than two minutes due to the response of a number of load resources.

Next, Mr. Sharma discussed response without load resources. He noted the loss of a 438 MW generator, which caused a rapid decline in system frequency. Generation increased as a result, and frequency was stabilized. The event was recovered in less than five minutes. Mr. Sharma next provided an example of a wind farm responding to a low frequency event. Wind was curtailed, which caused the decline in frequency. The units were then used to respond and recover system frequency. Wind has also responded to high frequency events.

ERCOT has the BAL-001-TRE-1 Standard, which is meant to maintain interconnection steady-state frequency within defined limits. Generation owners must specify droop and dead-band settings and pass rolling 12-month performance requirements for generation resources. ERCOT requirements include reporting transparency and changes to measuring frequency-measurable events, calculations for frequency response measurements, and calculation of 12-month rolling performance averages for each generator. As frequency control improves, fewer ancillary services are needed.

Mr. Sharma concluded his presentation by summarizing key points. There are misconceptions about wind and solar not being able to provide frequency response, when in reality they can provide very fast and sustained frequency response. Frequency control should come from a diverse set of resources. ERCOT uses generators, demand resources, and energy storage. Frequency must be coordinated, and cannot rely solely on primary frequency response. ERCOT saw big improvements in its primary frequency capability following implementation of BAL-TRE-001 Regional NERC Standard. Finally, frequency control must be coordinated. Primary Frequency Response must be coordinated with Secondary Frequency Controls. Generation dispatch must also take wind and solar ramps into account in addition to load ramps.

The third panelist, Tom Pruitt, Duke Energy, introduced the Resources Subcommittee (RS), which predates NERC. Its purpose is to assist the NERC Operating Committee (OC) in enhancing Bulk Electric System (BES) reliability by implementing the goals and objectives of the OC Strategic Plan with respect to issues in the areas of balancing resources and demand, interconnection frequency, and control performance. In addition to addressing frequency response and reviewing balancing authorities' control performance, the RS also examines inadvertent interchange, which is the mismatch between individual balancing authorities in an interconnection on their generation and load.

Mr. Pruitt's presentation showed a list of recent deliverables, most of which relate to frequency response. One in particular, Primary Frequency Control, is currently under revision. In 2013, the RS started conducting a generator survey for the Eastern and Western interconnections to align them to similar standards used in ERCOT. The RS initiated a standard authorization request (SAR) to change BAL-003, the frequency response standard. One of the reasons was that the interconnection systems have improved over time. A new focus is now on sustaining frequency response, and there has been significant improvement in this area. However, the current system penalizes generators for these improvements, which necessitates changes in standards. The second phase will focus on more aggressive changes, including on improving preparedness. Current standards measure performance, but it is also important to examine the necessary steps in advance of a potential event.

The fourth panelist, Ganesh Velummylum, NERC, discussed frequency response in the context of the Eastern Interconnection. Mr. Velummylum focused on a particular study that evaluated potential impacts of Eastern Interconnection resources shifting from synchronous generation to inverter-based resources (IBR). They compared 20,000 MW of synchronous generation to 20,000 MW of wind generation with and without primary frequency response. First, they benchmarked their model against a 2,100 MW resource loss and conducted a number of analyses. Mr. Velummylum pointed to his fourth slide on frequency response for 2,100 MW resource loss and said that the blue line indicates a wind replacement with 1% frequency droop, which gave the best performance. The graph also shows wind replacement without primary frequency response and with 5% frequency droop. The wind replacement with 1% frequency droop injected power in less than five seconds. Wind with 5% frequency droop setting is comparable to synchronous generation. Mr. Velummylum continued by providing an example of a 4,500 MW loss event that happened in the Eastern Interconnection. This occurred in 2007 and was the largest loss event to have ever occurred in the Eastern Interconnection. In the study, they also pushed further to examine a 6,800 MW loss event.

The study found that the 1% droop setting injects energy faster than the 5% droop setting. Mr. Velummylum also discussed the minimum headroom needed in the Eastern Interconnection for a 4,500 MW loss event. For synchronous generation, a minimum of 7,500 headroom is needed. Wind performs better than synchronous generation because it injects power faster into the system. Mr. Velummylum noted that high speed energy injection is needed for a system with low inertia. In fact, the lower the inertia, the more high-speed injection is needed.

In conclusion, IBR can outperform conventional generation governor action during the arresting phase of a frequency event; more energy can be delivered faster to rebalance the system. IBR also offers more controllable response and droop characteristics, deadbands, etc. can be tailored to the resource behind the inverter. Moving forward, they will continue to examine these issues, particularly frequency response headroom with high penetration of IBR for summer peak and light load conditions. They will also assess various combinations of droop characteristics and frequency responsive reserves for effectiveness in arresting frequency decline for high rate of change of frequency (RoCoF) events; and evaluate maximum IBR penetration with and without PFR under minimum inertia conditions.

EAC Discussion of Panel

Mr. Eto opened the discussion for questions.

Mr. Adams said it seems like inverter-based resources with 1% droop characteristics can outperform conventional resources. However, the economics push them to zero headroom, so Mr. Adams asked how they can make sure they always have headroom. Mr. Velummylum said that is more of an economic question and they are more focused on the technical reliability side of the research.

Mr. Adams noted that the phenomena of increasing wind and decreasing the amount of reserves is not necessarily a correlation of increasing renewables and improving performance. It is more indicative of having a team to make improvements in the controls. Mr. Sharma said the BAL-001-TRE-1 standard was what allowed them to improve system reliability and reduce ancillary services as more variable resources are added.

Mr. Eto said these nonconventional sources can have superior primary response characteristics. However, the question of whether they will be deployed is a markets question. For wind, it is the opportunity cost of generating power.

Tom Weaver asked to clarify whether the headroom required for IBR was smaller than the 7,500 MW required for synchronous generation for the 4,500 MW loss event. Mr. Velummylum responded that when 4,500 MW is lost, 4,500 MW in frequency response is needed. They picked 7,500 MW because they wanted some margin. The headroom needed for IBR has yet to be determined.

Paul Hudson asked about the stakeholder process of getting these standards approved when there are so many varying interests. Mr. Sharma said they are making incremental changes to their ancillary services requirements. There is currently a proposal undergoing the stakeholder process. Mr. Eto emphasized the speed of response. There was a proposal to divide up ERCOT's ancillary services market for primary control based on the speed of response. They were targeting the products they would like to get from the market based on the system requirements for primary control. Additional examples will arise as the requirements for frequency response become more severe in different interconnections.

Bob Cummings said the LBNL study was very timely in analyzing the concept of high-speed energy injection as a tradeoff that can mitigate the problems associated with lower inertia in frequency response. He said they will be publishing a frequency response phase two study. In April 2015, BAL-TRE-001 came into service and required all resources to provide frequency response. They created a frequency response reserve when they capped the frequency, which is a very positive finding.

Clay Koplin mentioned the cost of headroom with renewables is something they are examining and said it would be interesting to see how energy storage plays a role in frequency response. He also asked about the regulatory framework for getting load to contribute. Mr. Sharma said it is market-based. Loads bid their service on a daily basis and ERCOT procures one day ahead for

ancillary services.

There was a question on whether there is a need to conduct studies on secondary or tertiary frequency response. Mr. Eto noted that in their first study, they examined the interaction between secondary and primary frequency response. There is an important need for secondary frequency response, which is being addressed for many load forecasting analyses.

Michael Heyeck said all the standards focus on the generation side. The markets are able to deal with the headroom issue. Load is becoming more asynchronous than generation. Energy storage is another opportunity for addressing some of the issues. Mr. Eto said in the studies he has examined, load provides almost one-fifth of the primary response. There is redundancy in the system to ensure there is not over-reliance on a single resource. Therefore, having load be more responsive is highly valuable. Storage is an ideal primary frequency response resource. Both storage and wind are able to respond much faster than turbine governors, but headroom is needed. Mr. Pruitt said they do measure load response and are monitoring the contribution of load in each frequency event.

Mr. Heyeck asked the panelists for any recommendations for the Department of Energy (DOE). Mr. Pruitt said stakeholder involvement is important and always welcomed. Mr. Velummylum said they should take advantage of the technologies from inverter-based resources. These resources have speed and sustainability, so DOE should look at a collective of resources. Mr. Sharma said that loads are actually more effective in providing frequency response in times of low inertia. If ERCOT did not have participation of load resources, the amount of reserves they would have to procure would be very high. The cost would also be very high. He also noted that NERC standards are very effective. Dr. Ortiz said reliability is a property of the system as a whole. The studies that are supportive of that can shed light on the different roles at different levels of the system. These studies provide important insight for FERC, so Dr. Ortiz suggested that further work take a holistic view of the system. Mr. Eto recommended that DOE conduct research that will accelerate the adoption of nontraditional forms of primary frequency response, such as load, wind, and solar. Much of this can be done in the demonstration phase, to get acceptance and confidence in relying on these resources. The second recommendation is for DOE to exercise its role as a convener. They should encourage dialog between the end-use manufacturers and the power system communities that are in the best position deal with the issues before they threaten reliability. Third, DOE has provided resources to support NERC committees. For example, LBNL has built tools that these committees use for their frequency analyses. Mr. Eto said these resources are invaluable to NERC and industry.

Wanda Reder thanked all of the panelists.

Presentation: Grid Modernization Initiative Multi-Year Program Plan

Gil Bindewald, Director, Grid Communications and Control, DOE Office of Electricity (OE), provided an overview of the Grid Modernization Initiative (GMI), which he took on after Bill Parks retired from DOE in April. Mr. Bindewald began by providing a brief introduction about what GMI is and what it is not. GMI is not about investing in a focused technology or focused technique, such as energy storage or solar technologies. It is about recognizing that the power

system is comprised of a variety of pieces that the grid needs to integrate and inter-operate to achieve reliability and resilience. He noted that DOE needs to make sure they invest in technologies across different areas such as energy efficiency, fossil energy, nuclear energy, and cyber.

GMI started as an emphasis to improve internal coordination, to look for ways to coordinate and cooperate with a variety of stakeholders, to help reduce the likelihood of duplication between programs, to improve efficiencies, and to drive towards results in an effective way. It is important to recognize that the needs of the industry are being met and they are aware of and understand the breadth of technologies and investments that have been made in close collaboration and partnership with industry as well as DOE's National Laboratories and academia. Mr. Bindewald noted that Kevin Lynn is the co-chair and is co-leading this program, but unfortunately could not attend the meeting. He summarized the agenda for his presentation, which included the overview of GMI, Lab Call, peer review in September 2018, and recent GMI activities. The initial investment was $220 million over 3 years, and people were strongly encouraged to attend the peer review in September. He then transitioned to discuss the conventional grid and the challenges that come with it.

In conventional grids, there is a one-way flow with central generation, passive load, and little communication coordination. As a result, there is a variety of challenges and changes happening across the system, some of which include changes in supply mix, security threat, extreme events, and new market opportunities. It is important to change operational management through a security perspective and figure out ways to mitigate these events in a timely and effective way. One way to help this objective is to target investments. The ongoing GMI research focuses on bi-directional communication that recognizes that generation can occur from across the system, not only from a central perspective. The emphasis is on communication in a distributed system. Different assets and attributes can play strong roles in achieving the reliability, resiliency, and security objective. Security and resiliency are a philosophy that needs to be embedded from the basic design all the way up to operation, maintenance, and planning of the system. It is not about driving the cost of widget "A" down but being aware that it becomes a part of the system and understand how it contributes to the reliability, resilience and security overall. He stressed that this is not a single office or a single program, but it is about knowing that there is a breadth of contributors, both to the internal Department of Energy and to the broader sector. The roles of DOE's Offices of Electricity, Policy, and Science, among others, are building blocks that come together to contribute to fulfill the broader needs and objectives.

Mr. Bindewald mentioned that one of the focus areas was understanding how DOE's National Laboratories can be a resource, since they have both regional connections and technical strengths. One of the key challenges is to assess where the right investments can be made and be able to come up with solutions making sure there are no duplicates across labs. Building awareness and communications across lab complexes is another challenge. It is important to improve accessibility for private sector stakeholders that may want to take advantage or leverage these resources. There are 14 different National Laboratories, and trying to navigate all these connections and topics becomes overwhelming. One of the objectives of GMI is to make these resources more beneficial to those who want to pursue research and partnership with DOE.

Within the GMI, there are six focus areas: design and planning tools, system control and power flow, sensing and measurements, devices and integrated testing, security and emergency response, and institutional support. Mr. Bindewald went over a chart of these, and pointed out that they are looking to fill the vacant Security and Resiliency position. As a part of the GMI, they worked with labs and industry through regional workshops to develop the multi-year program plan with a set of basic objectives that include reliability, resiliency, security, and economics. The challenge is to better define each attribute and figure out a way to put measurements around these attributes to value the characteristics and encourage helping the system perform in a reliable way.

Mr. Bindewald gave a brief overview of the six areas of GMI:

- Design and planning tools, which consists of creating grid planning tools that integrate transmission and distribution and system dynamics over a variety of time and spatial scales;
- System control and power flow, which includes design and implementation of a new grid architecture that coordinates and controls millions of devices and integrates with energy management systems. There is a significant emphasis on controls and on sensors to support the integration of energy management system;
- Sensing and measurements, which deals with incorporating information and communications technologies and advances low-cost sensors, analytics, and visualizations that enable 100% observability;
- Devices and integrated testing consist of developing new devices to increase grid services and utilization and validate high levels of distributed energy resources (DERs) at multiple scales;
- Security and emergency response, which includes developing resilient and advancing security (cyber and physical) solutions and real-time incident response capabilities for emerging technologies and systems; and
- Institutional support that is comprised of conducting analysis and stakeholder engagement to help inform institutional decision-making.

He noted that investments happen over variety and stage. The majority of the focus in the initial phase was on the distribution side, but they recognize that there should be stronger ties with power, generation, and consumer interaction.

Mr. Bindewald then moved on to summarize the 2016 Grid Modernization Lab Call, which covered 13 of DOE's National Laboratories, over 88 projects, and more than 150 partners. The Lab Call was divided into four different areas. The first area dealt with identifying the overall metrics. The second focused on five projects related to overarching strategies, such as testbeds, sensors, and standards, and working towards integration and operability. These are key themes that cut across technologies, and it is important to work collectively. The third area focused on regional engagement and recognizing that technology investment from research stance is important. There is regional variation along with market and policy implications that need to be considered. The goal is to effectively move the research out of the lab into deployment and demonstration and working in partnership with the stakeholders. GMI is asking for suggestions from EAC members on ways to do this effectively. He noted that some of the project partners from the initial Lab Call were from academia, industry, as well as the states. It is important to

break boundaries and engage with stakeholders more effectively to help move the technologies into practice, as appropriate. He then transitioned to discuss architecture and the interconnection seams study.

Architecture is not about designing or developing a particular object. It is about trying to set in place a context that will allow the flexibility to accommodate a variety of technologies. Architecture is about making sure the options stay available for as long as possible to allow them the flexibility to adapt and adjust to the changes. This becomes very important while considering things like uncertainty and infrastructure investments that are decadal instead of annual.

GMI looks at how data mining and new analytic approaches can be applied to extract data and turn it into something that supports reliability and resilience. Mr. Bindewald commented that part of the focus in the initial Lab Call was more about how the data can support management systems – i.e., whether it would be possible to understand more about the assets themselves, to be able to understand signatures, and predict asset behavior. There is a lot of focus on flow batteries as well as manganese oxide and electrochemical batteries. From a system standpoint, there is fall back to energy storage. It is necessary to have broader capabilities on understanding how these pieces could come together and address the concerns. One project is about virtual battery storage and the techniques to meet system objectives and bring in demand response for the purposes of resilience and reliability. Another effort is about New Orleans, which focuses on recognizing there is a variety of approaches in terms of what the drivers and objectives are. In addition, this effort focuses on microgrids and ways in which they can support resilience.

Mr. Bindewald provided a brief overview on the institutional support. He pointed out that a lot of the institutional support is an extension of the work Katie Jereza's office is doing. Their focus is on technical assistance, supporting states, and other regional decision makers in terms of navigating technical as well as institutional issues that may come up.

The peer review held on April 18th, 2017 in Washington, D.C. was widely attended. Good feedback was received on the projects but much more response was received on the poster presentations. There were many projects with partnerships. Mr. Bindewald said that the main takeaway from this peer review was the recognition of how there were capabilities and strengths at both the principal investigator level and organizational level. The attendees came forward and said that they might be able to help and figure out a way to work together, which is what the GMI is really about. He then transitioned to discuss about Resilient Distribution Systems.

The primary recipient of Resilient Distribution Systems was the Grid Modernization Laboratory Consortium. There was a lot of focus on control, which created a gap. One big challenge in 2017 was to figure out ways to increase the penetration level of photovoltaics or energy storage on technology X on the distribution level. With the new leadership, it was necessary to justify how this work contributed to resilience. Seven projects were awarded. The focus was still on some of the National Laboratories with two additional focuses. There were cybersecurity requirements and cybersecurity plan, regardless of the nature of the research or requirement, and being able to understand how that plays into the technology and being able to enhance from the ground up. He mentioned that they leveraged some work that Chuck Goldman has been doing at LBNL, and have an overarching analytic team that will help GMI improve the relationships that they are

setting up on a regional level to be able to take and share those lessons learned over other regions and areas. There is a formal mechanism in place to help, guide, and provide insights on a project-by-project basis with each of the regions and areas.

Mr. Bindewald quickly went over the project locations and moved on to talk about the six projects. He focused his discussion on Resiliency and Energy Storage, which he pointed out is slightly different. This project is about coupling community resilience with utility reliability. It looks at the metric from a community standpoint that is interested in maintaining the critical load, facilities, and services – services which include energy, water, waste, transportation, and communication – and finding out how this couples with reliability objectives that the utility would have. The project also considers the impacts on investment decisions and if there are ways to improve these metrics and improve connectivity across different areas. The other projects include Clean Start, Laboratory Valuation Analysis, and regional work with virtual micro grids in Alaska.

Mr. Bindewald moved on to discuss valuations and the idea of cost-benefit. He noted that leveled cost of energy (LCOE) is not a bad metric but it is incomplete, and it is necessary to recognize that it goes beyond energy. It is also important to consider other services and value that play into this, which could help understand and balance out some portion of the cost.

The next GMI peer review will be held September 4-7 in Pentagon City, VA. The activities will include reviewing DOE's grid modernization portfolio, listening to industry leaders discuss the future grid during a panel discussion, reflecting on the updated Grid Modernization Multi-Year Program Plan, hearing from leadership at the National Laboratories discuss future grid activities, and engaging with other GMI projects in the portfolio during the poster session. It is important to recognize that resiliency and security need to play a more prominent role. There is a desire to expand regional engagement and figure out appropriate ways GMI can continue to expand and continue this effort. Mr. Bindewald encouraged people to attend this peer review if they are interested.

Ms. Reder said that she appreciated the update. She pointed out that there is evidence of good work since GMI has done so much to reach out to industry and to coordinate across the labs. She asked about internal coordination and how the GMI lab work ties to the goals that have been presented and in what ways they can be reinforced. Mr. Bindewald responded that all the work on the R&D side fits within the GMI umbrella. The roles of modeling, sensor, energy storage, and cyber are relatively prominent. Devices were not necessarily the focus area in the first Lab Call but now they are reconsidering them, especially energy storage and flow controllers. There has been much advancement both within applied energy programs as well as RBE. Ms. Reder then asked if it is possible to look at the commercial factor to get it out in the industry with the help of DOE. Mr. Bindewald replied that a lot of the focus within their budget has been shifting to the early stage and figuring out where DOE can play a role, most likely on the fundamental side. He mentioned that they are interested in hearing thoughts on ways to expand DOE's role. The key is to make sure that this research not just hits performance and technical goals, but meets the ultimate needs of the industry and its being adopted and adapted. Ms. Reder said that there is a lot in motion from the mapping to the goals of the model. Ms. Reder stated that even though GMI is a five-year effort for $200 million, the work is not always evident. She pointed

out that she is learning on a high-level slide basis and encouraged having a mapping of how this research is feeding the model and the overall goals. Some more work needs to be done by either setting up a panel or augmenting the stakeholder involvement process to leverage the good work GMI is doing. Mr. Bindewald thanked Ms. Reder for her comments.

Richard Mroz commented that he was pleased to hear about how security and cybersecurity measures were integrated into the research. He asked about capturing cost issues and being able to segregate what the cost is associated with, such as the distribution-level cost and other costs. Mr. Bindewald responded that separation of cost has been difficult, partly because if a technology is connected to one point in the system, the impact on reliability can have a broader effect. He pointed out that the New Orleans project highlights this perfectly, where microgrids at the local level support things like flood control, but when rolled up it has broader bulk power system benefits. He noted that their focus is on LCOE area and energy storage area. The challenge has been to have technology that is able to serve multiple roles. However, this adds investment challenges. The goal is to have a flexible technology that is able to adapt and change when exposed to a variety of conditions. It can help in terms of reliability or broadening another service. He mentioned that this fits well with a lot of work that TPTA has been doing. DOE funded a report with the National Academy of Sciences that came out last summer. Its key theme was to recognize resilience in terms of where it fits and how valuation comes into play. Mr. Mroz asked, in terms of the management of DERs that goes to the dispatch issues, if there is any specific work looking at the platform for optimizing DER. Mr. Bindewald responded that there have been multiple levels of optimization of DER. He pointed out that distribution energy resource management systems (DERMS) and advanced distribution management systems (ADMS) work as part of energy management systems (EMS). There are two objective functions: the objective function from a system view for the use of the DER resource and the objective/optimization function from an owner or asset capability of that resource. The key is to understand how compatible the two objective functions are and be able to recognize any conflicts.

Dr. Kezunovic commented that they might not be able to optimize in the sense they know optimization on how the grid operates, which changes the paradigm. He asked how much analysis of behavioral aspects is associated with these projects and what the next steps are. Mr. Bindewald replied that there are two groups of projects dealing with behavioral response issues. The first deals with the traditional operator and queuing mechanisms to support reliability and resilience. At least in the near term, a human decision-making process is going into optimization around the resources and the dispatch scheduling of those resources. There is also the behavioral piece around the consumer side, and there has been work in the valuation activities. The goal is trying to understand the separation between services and valuation and ways to quantify this. He pointed out that a lot more work needs to be done as they have not gone into as much depth to be able to understand the response. It is essential to look at the responsiveness of demand and be able to characterize the load as it is emerging. It is no longer about the maximum load, but about the behavioral capabilities and what characteristics behind the meter are playing a significant role. DOE has had several projects dealing with load modeling but most of those were enhancement of conventional approaches.

A participant commented about attending the kickoff meeting of the DERMS guideline. Keeping

this in synch with GMI is going to be important to avoid double counting of resources behind the meter. Mr. Bindewald appreciated the comment.

EAC Energy Storage Subcommittee Update

Ramteen Sioshansi, EAC Energy Storage Subcommittee Chair, provided a brief update on the two white papers the Subcommittee is developing. Dr. Sioshansi began with the 2018 Biennial Energy Storage Review. The Energy Independence and Security Act of 2007 (EISA) required the formation of the Energy Storage Subcommittee. This Subcommittee was formed in March 2008 in response to Title VI, Section 614 (e). Title VI, Section 641(e) has two parts pertaining to this subcommittee:

1. Section 641(e) (4): "...every five years [the Energy Storage Technologies Subcommittee], in conjunction with the Secretary, shall develop a five-year plan for...domestic energy storage industry for electric drive vehicles, stationary applications, and electricity transmission and distribution."
2. Section 641(e)(5): "...the Council shall (A) assess, every two years, the performance of the Department in meeting the goals of the plans developed under paragraph (4); and (B) make specific recommendations to the Secretary on programs or activities that should be established or terminated to meet those goals."

Dr. Sioshansi noted that they conduct Section 641(e) (4) every four years instead of five years to make it in conjunction with the bi-annual storage reviews. He then briefly discussed the EISA requirements. The "2016 Storage Plan Assessment: Recommendations for the U.S. Department of Energy" that was approved on 29 September 2016 fulfilled both requirements. The Subcommittee is currently working on the "2018 Storage Plan Assessment: Recommendations for the U.S. Department of Energy," which is proposed to fulfill the second requirement.

Dr. Sioshansi commented that the scope has broadened in the past years. The 2012 review focused exclusively on storage-related activities of OE. The 2014 review expanded the 2012 scope to include OE, the Office of Energy Efficiency and Renewable Energy, Advanced Research Projects Agency-Energy, and the Office of Science. The report also examined coordination between the Department and other Federal agencies (e.g., National Science Foundation and Department of Defense). This was in line with offices and agencies that were included in the Department's overall strategy. The 2016 review maintained the same broad programmatic scope, but the technological scope was expanded beyond electricity-in/electricity-out storage, and power-to-gas, thermal, and virtual storage were included. The 2018 review is proposed to maintain this same breadth as the 2016 review.

Dr. Sioshansi said the Subcommittee is building off what they did in the 2016 assessment. In 2016, the Subcommittee used an external interview process, which had "users" and "implementers" of the Department's storage program who informed the assessment and recommendations. The interviewee group included different sets of stakeholders, such as energy-storage developers, energy-storage deployers, state policymakers, independent system operators (ISOs)/regional transmission organizations (RTOs), NERC, FERC, non-governmental organizations, renewable developers, and energy and environment think tanks. The Subcommittee plans to gather feedback of interested parties during the DOE OE Energy Storage

Peer Review 2018 in Santa Fe, NM in September. In addition, they will conduct telephone interviews to supplement the peer review interviews because they will not be able to talk to everyone of interest at the peer review. The Subcommittee received the Department's response to the 2016 review in April 2018, and is using that to guide the 2018 assessment. The working group is trying to finalize the desired interviewees, and determine who is going to be at the peer review and who needs to be approached for the telephone interviews. The Subcommittee is targeting March 2019 for EAC approval.

Dr. Sioshansi then provided an update on the Rate, Tariff, and Market Design for Energy Storage Work Product. Energy storage is a unique power system asset that can behave like different types of assets: generation, load, transmission, and/or distribution asset. Storage can provide services, some of which are market-priced or market-contingent, and others that are not. The traditional regulatory and market-design approach that has been developed over the last 20-30 years has treated assets as either being market- or rate-based, which may not be suitable from a regulatory or market-design perspective for integration of energy storage into the electric power system. The aims of this white paper are:

- Raise the problems created by historical market, rate, tariff, and regulatory designs as they pertain to energy storage;
- Survey what has been implemented in practice and proposals on the table to address these issues;
- Make recommendations for further work or study;
- Help the Department assist state regulators and legislators determine how to address energy storage within regulatory proceedings, market designs, and legislation;
- The Department should not be prescriptive, but provide input and options based on current and past regulatory decisions and evolving storage-related science, applications, and research; and
- Fits theme of Secretarial Directive on Regulatory Reform.

Dr. Sioshansi mentioned that they have been developing this white paper based on the EAC Panel Session in the February in-person meeting. The Subcommittee received perspectives of industry, RTOs, state regulators, and FERC. Last month they had a briefing, which was put on by DOE and the national labs. The idea was for them, as a working group, to see what DOE and the National Labs have been doing in this regard so that they do not make duplicate recommendations. He pointed out that it was very illuminating and useful to see what DOE and the Labs have been working on.

The next steps for the Subcommittee are to debrief on the panel session and webinar, outline and scope the white paper, determine if further expert and outside interviews are needed, and meet the March 2019 target for EAC approval. Dr. Sioshansi noted that, after the conclusion of the EAC Meeting, the Energy Storage Subcommittee will be meeting starting at 1:00 PM and opened the floor for questions.

Mr. Heyeck pointed out that the Subcommittee has a good slate of work products through March of next year. He asked Mr. Hudson to speak about their discussion from the previous day regarding the types of grid scale. Mr. Hudson said that a lot of knowledge is being developed on the ground and it is important to be in dialogue with that community to look at some microgrid

providers that are trying to get to scale. There are many small individual companies that have done specific projects. DOE has a database of the energy storage space but, in the broader sense, there seems to be a number of vendors that are not represented. He noted that it would be useful to continue to build on these types of partnerships.

Dr. Sioshansi noted that the Subcommittee took a 5-6 month break from developing any new work products to give DOE an opportunity to review previous work products. Now they need to think about other white paper ideas to pursue, which is on the agenda for the subcommittee meeting in the afternoon. Mr. Heyeck mentioned that the transition of Administrations created some of the backlog. He thanked Dr. Sioshansi for the update and invited Mr. Adams to give an update on the EAC Smart Grid Subcommittee.

EAC Smart Grid Subcommittee Update

Mr. Adams, EAC Smart Grid Subcommittee Chair, provided an update on the Subcommittee's activities and plans. He said that Ms. Reder, who was the previous chair, was tremendously efficient as she managed to close out all previous work items during the web-based meeting on June 25th. The Power Delivery Subcommittee and the Smart Grid Subcommittee were merged recently. Mr. Adams asked as many people as possible to participate in this combined Subcommittee, and added that they were looking for volunteers for the vice chair role. In addition, DOE has developed a new template for work product recommendations limited to seven pages, including a title page and a reference page.

Mr. Adams provided a brief overview of their recent work. Five papers were approved by the EAC in June 2018. The most recent deliverable was about enhancing grid reliability with integrated storage from electric vehicles, which was approved in June. The deliverable is short and uses the new template. He encouraged the Subcommittee members to review the recent deliverables. The Subcommittee has done work in expanding the electric delivery system, alternative regulatory models, modernizing the delivery system, and smart grid research. The Subcommittee has also made EAC recommendations on grid modernization, moving forward on grid modernization, distributed energy resource valuation integration, and new technologies on modern grid; and conducted a panel on frequency response and grid resilience. These work products are posted on the EAC website along with the vehicle integration. Mr. Adams then transitioned into a discussion on the recommendations.

The Subcommittee provided recommendations on the value of a VAr, the transmission-distribution interface, and EAC regulatory reform. Mr. Adams noted that all these documents use the new template and are five pages or less. In addition, the Subcommittee organized a panel on "Development of a North American Grid Resilience Model." They have identified some priorities for further development and have received feedback from the Department. They will be working to set up a panel for the October meeting and presumably work as a group to develop deliverables for DOE to consider. The five pillars for which the EAC has been given guidance are:

- Puerto Rico and US Virgin Islands Restoration and Resiliency Efforts;
- North American Energy Resiliency Model, which the EAC talked about yesterday;
- Mega-Watt Scale Grid Storage;

- Revolutionize Sensing Technology Utilization; and
- Operational Strategy for Cyber and Physical Threats.

The Subcommittee will strive to understand what DOE is doing since their regulatory mandate requires them to provide recommendations on DOE's current work. Mr. Adams acknowledged Michael Pesin's R&D portfolio and Gil Bindewald's presentation on Grid Modernization Initiative. He pointed out that their four-day public meeting is coming up in September and encouraged people to attend. This meeting will give an in-depth look at what the Department has been working on, which is necessary to understand to make the right recommendations.

Moving forward, the Subcommittee needs to come up with a topic and develop a panel for the upcoming EAC meeting. They need to develop the work products to recommend to the leadership committee. Mr. Adams discussed the suggestions they have received so far. For the panel, there have been suggestions for members on data analytics and impacts of big data, which apply to resiliency topics. Another suggestion for a panel was on new businesses with various products that could have value within the utility industry. He pointed out that their next meeting is after the Grid Modernization Lab Consortium (GMLC) peer review, which presents an opportunity. Future EMS, DMS, and market management systems (MMS) needs and expectations need to be discussed. He noted that he does not expect the decision to be made now, but wanted to get these ideas out since they will have to start working on these panels and work products immediately. He commented that the Subcommittee will talk through the work products that have been proposed in their next phone call. He asked for questions.

Ms. Reder suggested that, after hearing Gil Bindewald's presentation on GMLC, there may be an opportunity to parallel what they did in Smart Grid during the ARRA investments. She said that there was a report out on the major projects after every single call. There was ultimately a dashboard or report that came out as part of the Committee report. She emphasized that the dialogue helped in understanding what was going on with all of the projects in the portfolio. There may be an opportunity to do the same with the GMLC in which they could understand the various projects that are in motion. There might be a way to build the iteration and dialogue between Committee and project to provide timely feedback into Mr. Bindewald's work. She added that, for the panel, there were discussions on transmission, modeling, generation, and modeling on a very high level, which she thinks is important. She pointed out that knowing what is happening behind the meter and on the distribution side raises a lot of uncertainty. They could have a panel around load and behind the meter to better understand what is happening in the community.

Mr. Adams said that he liked the idea, but asked Ms. Reder to link her panel suggestion to one of the five pillars. Ms. Reder said it would fit under resilience. She noted that there has been a lot of resiliency discussion at a very high level, and this topic needs to be brought to the table. Mr. Adams commented that he will get the Subcommittee to agree on it before making any commitments.

Mr. Heyeck pointed out that the resilience model cuts off at transmission, and getting to the distribution side is a challenge. The volatility and variability at the distribution level are astounding. The transmission and distribution (T&D) interface paper points out the blur between

T&D but there is no blur between FERC and the state utility commissions. He noted that some companies on the data analytics side do not know much about the grid or grid operations. He provided an analogy of driving 65 miles per hour and opening one's eyes every 5 seconds. Synchrophasors are relegated to back servers for forensics. Mr. Heyeck pointed out that Dr. Kezunovic noted regarding the panel that the metrics and foundation of Supervisory Control and Data Acquisition (SCADA) and EMS systems are basically the SCADA framework. Synchrophasors are needed to provide signatures. Mr. Heyeck added that it will be hard to get a crossover of internet-of-things people who know the grid. The panel would have to consist of people from both information technology and operational technology. This would be extraordinary for not only the resilience model that could feed up, but also the signatures that could provide feedback on cyber and physical threats. In addition, he was astounded by the frequency response: 99% on the generation side of the world and 1% on load side of the world. Experts are needed to recommend how to build in adjustable speed drives and other load elements to provide frequency response in an organic way. He commented that he is not sure if the industry would want to spend money on the load element, so there will be a cost benefit on the other side.

Mr. Adams argued that the third-party market needs to have an incentive and a revenue stream to provide service. Mr. Koplin pointed out that beyond the meter there is a smart grid future where a higher speed SCADA system will be transacting with industrial customers. The key is to have transactions between the dispatched energy. He added that a cybersecurity element is involved. Mr. Adams responded that they can have a discussion on this topic later so that he can provide details on how this could turn into an idea for the panel. He thanked Mr. Koplin for his comment.

Mr. Weaver added that, as they involve the customer, even from a planning standpoint, they need more information on what is happening on the other side of the meter, which is a challenge. It is necessary to come up with a secure way to exchange information across their firewall in a way that can be used without compromising their security. Mr. Adams mentioned that they received many panel ideas and asked the Smart Grid Subcommittee participants to start thinking about it since they need feedback to proceed. Some of the ideas for work products that were brought up include inter-operability requirements for dispatch systems, technology investments strategies, integrated planning methods, and GMLC review. He noted that the review will be important. There were no further questions.

Public Comments

There were no public comments.

Wrap-up and Adjourn Day Two of July 2018 Meeting of the EAC

Mr. Heyeck, EAC Chair, gave Ms. Jereza an opportunity to say a few words. Ms. Jereza thanked everyone for attending the meeting and welcomed new attendees. She highlighted some key points from the resiliency model discussion as takeaways. She noted that they want to be able to give planners something useful and actionable, which could also be used for industry. She encouraged people to think about what a n-k model would look like, what the goals are and how good is a good model. She then mentioned the four things Dr. Ghassemian wanted to get

feedback on. The first thing was data handling with the resiliency model. They need to prime that pump, so that when the model is ready they can collect data, store it, and share it. The second is industry involvement, which is more for her group to take on. She said she will let the attendees know the stakeholders they are engaging with so that they can help DOE fill the gaps. The third is model validation, which might be tough. The fourth is information sharing, which will have many levels. Part of the model will be on the classified side, so the challenge is to share it successfully. She thanked everyone once again for coming to the meeting and said that she looks forward to seeing them again at the next meeting.

Mr. Heyeck thanked Ms. Jereza for her remarks. The next EAC meeting will be held on October 17th and 18th, starting at 1p.m. and ending at noon the next day. The Smart Grid Subcommittee meeting will be held before the EAC meeting, and the Energy Storage Subcommittee meeting will take place after the EAC meeting for the face-to-face meeting opportunity. In 2019, the EAC meetings will take place in March (13 and 14), June, and October, typically a Wednesday and Thursday, based on the availability of the meeting room. He pointed out that the two Subcommittee chairs provided information on the next steps. He noted that the EAC is comprised of experts, regulators, legislators, and policy makers. They have a diverse committee, and they provide DOE with recommendations. He commented that everyone signed up for at least one or more Subcommittees. He made an analogy that resilience is a 400-pound marshmallow, which can be boiled down to many marshmallows by taking one step at a time. He suggested taking 18-24 months to figure out what can be built. He believes that there is low-hanging fruit, which the Smart Grid Subcommittee could tackle. He then asked Matt Rosenbaum if he had anything to add.

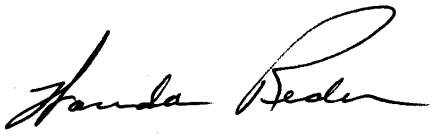
Mr. Rosenbaum thanked everyone.

Mr. Heyeck asked if there was any objection to adjourning. There were no objections. The meeting was adjourned.

Respectfully Submitted and Certified as Accurate,

Michael Heyeck
The Grid Group, LLC
Chair
DOE Electricity Advisory Committee

02/20/2019
Date



Wanda Reder
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