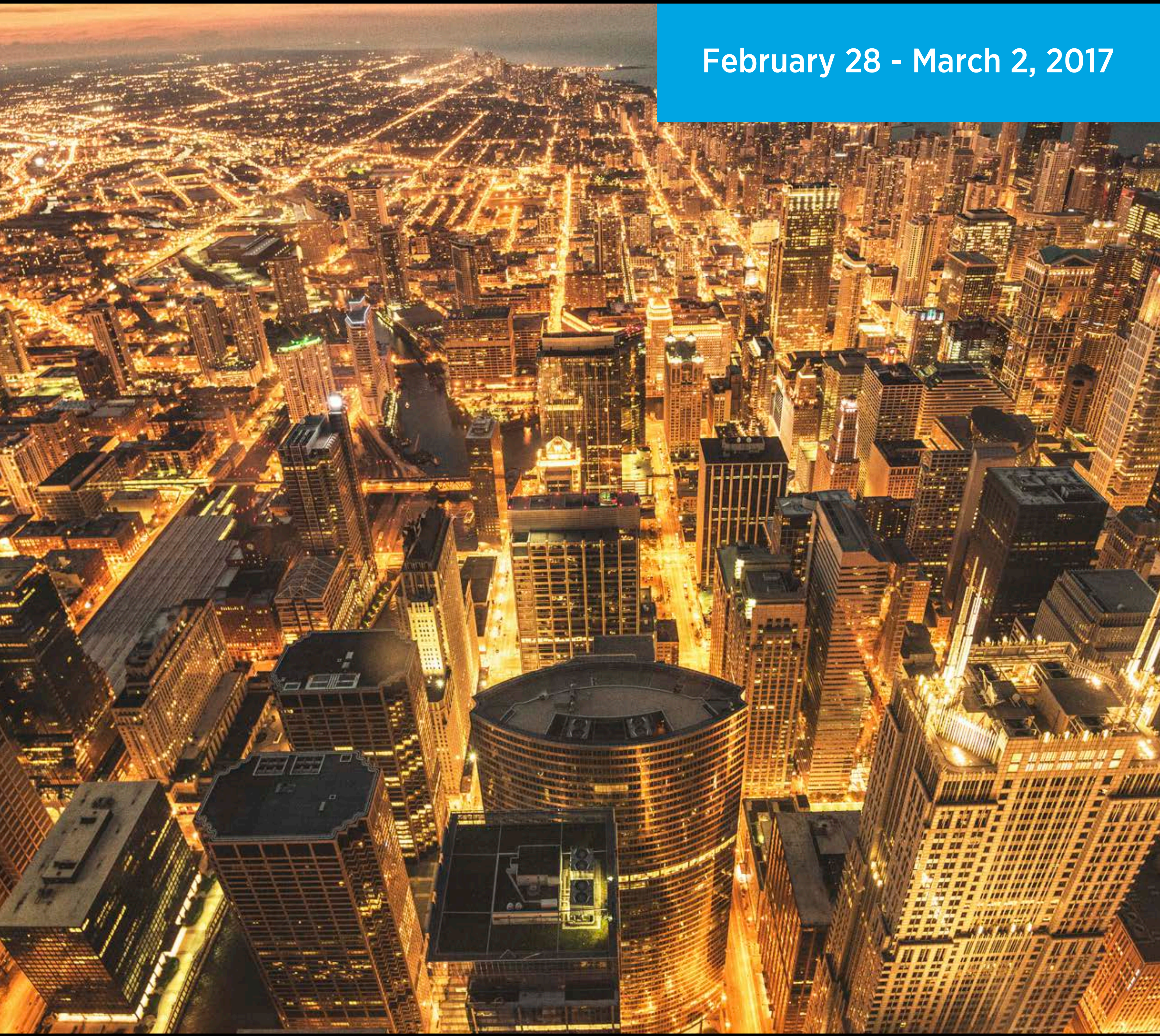
Opportunities for Grid Modernization Collaboration

U.K.-U.S. Grid Modernization Workshop Report



February 28 - March 2, 2017

Introduction

At the request of the UK Science and Innovation Network,[1] a U.K.–U.S. Grid Modernization Collaboration Workshop was held at the U.S. Department of Energy's National Renewable Energy Laboratory (NREL)[2] in Golden, Colorado. The workshop brought together experts from internationally recognized utilities, technology companies, emerging organizations, universities, and research laboratories. Attendees from all of these sectors significantly contributed to the gravitas, context, and focus of the sessions, sharing meaningful content and discussing potential future developments in grid modernization. *(For a full list of the participants and their organizations, see the appendix in the back of this report)*.

The goals and objectives of the workshop can be summarized as follows:

- Share the challenges of grid modernization in the United States and United Kingdom.
- Share insight into some of the programs and activities underway via different mediums in the United States and United Kingdom.
- Share insight into laboratory and facility capabilities to perhaps stimulate co-funding research programs and co-use of facilities and enable mutually assured testing and verification programs.
- Leverage the ability to engage with industry partners throughout the United States and United Kingdom.
- Establish relationships to enable future collaborations in exchanging researchers and forming industry partnerships and programs.
- Establish the baseline to build future relationships and share programs to help accelerate industry engagement, participation, and grid network transformation.

The workshop was designed to enable active discussions rather than simply share information by presentation. Inevitably, a significant amount of presentation material was used; however, only about 35% of the allocated workshop time involved previously prepared presentation material, and 65% of the time was dedicated to discussions or brainstorming activities. These activities proved to be highly effective in engaging all participants throughout the duration of the workshop, and they resulted in high-quality outputs, such as ideas for future collaboration and a number of immediate to long-term action items. These included the co-development of advanced tools; cross-border training; joint proposals; and replicating experiments or capabilities across labs.

This report primarily follows the running order of the workshop, and importantly, it identifies opportunities for future collaborations between individuals as well as collective entities. Turning some of the noted opportunities into tangible actions will prove challenging; however, with active participation from industry partners, utilities, and research organizations, many exciting opportunities for research and development of advanced grid technologies are possible. Organizers of the workshop encourage participants and readers of this report to take ownership of these goals and drive the next steps included here in the most naturally occurring way at the individual level. A follow-up session is being considered to further engage the collaboration and focus that was generated by this initial workshop.

[1] https://www.gov.uk/government/world/organisations/uk-science-and-innovation-network

[2] http://www.nrel.gov/

Overview of Grid Modernization

A number of presentations and discussion sessions helped to establish a solid understanding of the current electric grid landscape across the globe, with respect to smart technologies and grid modernization. An exploration of key developing themes within these sectors included:

- The drive to a carbon-free world, with the Group of 7 (Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States) leading the charge by leveraging policy that can influence the use of technologies to support a more modern grid.
- The drive toward electric and hydrogen fuel cell vehicles. As indicated in the overview presentations on the United Kingdom's electric grid landscape, there could be 2.5 billion vehicles on the road by 2050, compared to the 0.5 billion today. A key difference is that the vehicles of tomorrow will be carbon-free.
- The electrification of heat, either by transporting electricity to developing areas that do not have electricity today or in developed countries by converting gas (carbon-based) heating systems to those powered by clean, renewable sources.

Workshop discussions recognized that these themes present a significant number of opportunities and challenges for electric grid networks today and how they might evolve in the future. Participants also recognized that the timeline associated with the directional change toward improvements was not clear; however, with the thrust led by government, progression is possible by industry participants contributing to and shaping the future. Technology solutions and market drivers both have the potential to accelerate or decelerate progress. Notably, customer pull through social science engagements and the socialization of energy networks were also recognized as key pieces in accelerating the journey toward a modernized grid.

Taking all of these factors into account, participants agreed that the combined efforts of academic/research institutions and industry can help meet the objectives of future grids to support and enable a smart, low-carbon world.

Focal Points

Three primary topic areas were selected while planning the workshop: devices and systems integration; sensing and measurement; and communications, cybersecurity, and resilience.

Devices and Systems Integration

A significant topic for discussion was the recognition that a smart distributed energy system in the future will have not only more hardware devices connected to the grid but also the ability for the devices to interact through communication mechanisms.

Sensing and Measurement

A prime focus was the need to access and mine information in the appropriate quality and quantity to enable necessary decisions to be made timely and efficiently.

Communications, Cybersecurity, and Resilience

System operators pride themselves on the resistance of their energy networks to the threat of cyber-attacks. These threats are increasing. Historically, these threats have been largely managed through the private and unconnected nature of a utility's operation systems; however, as information and operation systems begin to merge, combined with the drive to connect with customers to manage generation and demand at the local level, protection against cyber-attacks and the ability to maintain secure and resilient electric power supplies are continually being tested. This topic offered much substance for discussion among all participants.

The Electric State of The Globe: Smart Grids Around The World

Throughout the course of the workshop, participants discussed the current electric grid landscape across the globe with respect to smart grid implementations, some of which are documented here. In general, attendees considered that technology solutions have the ability to transcend geographic boundaries with relative ease, perhaps because the manufacturing base is keen to exploit international markets; however, market-led solutions and the applications of technology solutions depend on the market environments of specific geographic areas. For example, the applicability or emergence of smart metering has been very effective in places where the economic environment mandates the implementation of a smart meter solution (in some cases perhaps associated with electricity theft).

An additional observation was that the pace of technology implementation in developed countries can be significantly slower than that in developing countries. This might be because the urgency of achieving connection and the need to comply with less developed regulation often enable speedier implementations; however, this observation cannot be globally applied.

South America

Most electricity networks in South America are owned by the state, and there is virtually no free market participation associated with energy production. A few smart city projects (e.g., Santiago and Rio de Janeiro) have been undertaken involving integrated systems such as storage, photovoltaics (PV), and lighting. Significant effort has been extended to rolling out smart meter programs in a number of countries; however, this primarily targets a reduction in energy theft.

Middle East

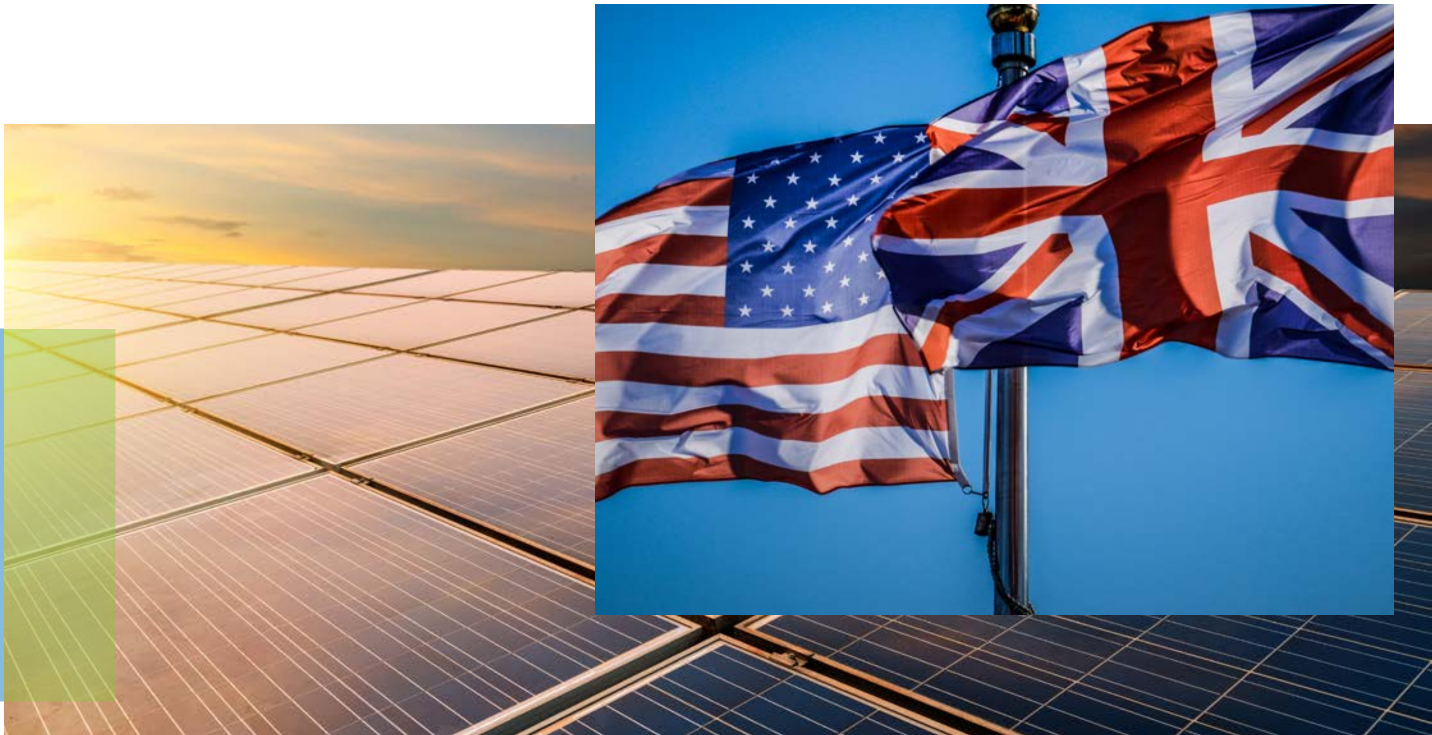
As a region, significant year on year demand growth is anticipated for energy markets (more than 7% per annum) in the Middle East. While most of this growth will be achieved through the construction of large thermal (oil and gas) power plants, there is a significant focus on distributed energy resources (DERs). Renewable resources and DERs are on the agenda in the region, along with the construction of international transmission.

India

The utility infrastructure in India is state-owned, and the theft of energy is a huge issue; consequently, a smart meter program is targeting national improvement in reduced energy losses. Many individual homes are not connected to the grid, and a large secondary market of small-scale domestic generators provides electricity. The country's priorities are to first connect those who are not connected and second to address the theft of energy. The state has emerging plans around integrated smart grids for the future.

China

China has a series of five-year plans targeting smart grid development mandated by the state; however, because state-based technology deployment is increasing at a significant pace, and because of the state-based nature of the infrastructure, there is little free market development. Deploying technology and investing in infrastructure has the potential to transform the energy sector in China. Many emerging technologies can be evidenced here, and may well be transferable to other parts of the world."



Australia

Many examples of DERs and associated projects are found in Australia. Importantly, a significant number of feed-in tariffs and market trials have been undertaken. The opportunity to be self-sufficient in electricity in some territories has been created. This is a challenging use of the system for utility companies, and consequently there is the potential for a disruptive electricity market reformation to occur with pace.

In discussing these observations, there was emerging thought that markets should be created by policymakers to enable local networks to meet the balance of supply and demand.

United Kingdom

During the workshop, speakers from the United Kingdom shared an outline of the funding mechanisms for the U.K. energy sector. As noted, policy drivers have supported significant investments in distributed generation (solar plus PV), and consequently the drive to decommission large thermal power plants continues. From a network perspective, innovation mechanisms enabled by the U.K. regulator to stimulate utility companies to respond to the low-carbon proposition were shared. This funding route has enabled a number of research facilities and laboratories to be established in the United Kingdom that focus on the drive toward a low-carbon future.

The Energy Systems Catapult[3] is compiling an overview of the energy capability landscape in the United Kingdom. Typically, research facilities in the United Kingdom operate on an open-access basis; therefore, the visibility of these facilities is key for access to be achieved.

At the implementation level, information was shared on the significant investment in facilities being prepared by the National Centre for Energy Systems Integration funded by the Engineering and Physical Sciences Research Council. Once established, these facilities will lead studies of the interaction of the social science aspects of energy use and human behavior, using market-led activities and new technologies. These will present a significant and valuable living laboratory environment to enable holistic solutions in the future.

The Power Networks Demonstration Centre (PNDC),[4] hosted by the University of Strathclyde,[5] is another example. This facility presents a megawatt-scale distribution network at 11 kV, DC, and low voltage. It provides a safe, customer-free environment for products and integrated systems to be evaluated for operational deployment, including invertor testing, protection testing, power-hardware-in-the-loop demonstrations and communications, and control and protection activities.

United States

From a policy perspective, the drive toward a modern grid in the United States is being led through the U.S. Department of Energy's (DOE's) Grid Modernization Initiative.[6] Through this platform, DOE initiated a significant number of activities in the national laboratories, particularly at NREL. Each laboratory is leading specific areas of research and collaborating on, creating, and delivering work in a structured approach to program management. Some details of these programs are described later in this report, and they provide perspectives on potential future interagency and international collaboration. One goal of the Grid Modernization Initiative is to provide ease of access to and information on the strengths of the national laboratories in order to leverage their capabilities on a broader level.

NREL's Energy Systems Integration Facility (ESIF)[7] was funded specifically to enable integrated energy solutions, and workshop participants shared some of the goals of NREL's and DOE's research-and-development programs. Specifically, security, resilience and reliability, market assessment, advanced modelling techniques, and the shift from large thermal power plants to significant penetration levels of DERs were highlighted as areas of interest.

The advanced computing power of the ESIF was also demonstrated, highlighting the need to manage many more control points when operating an electric grid because the number of DER devices is already significant and increasing. Moreover, the turn-off/turn-on frequency is also greater because the impact of solar, wind, and peaking plants varies during a 24-hour period. An effective video presentation on this topic was shared.

An overview of the U.S. landscape concluded with a tour of NREL's ESIF, wherein projects are under evaluation on topics such as a hybrid generator solution, micro generation solutions for critical infrastructure, domestic-level grid participation, models, and cybersecurity.

Europe

Turning to other nations throughout Europe, presenters discussed the funding landscape of European grant structures toward a modern electric grid—and high-level details of the European Distributed Energy Resources Laboratories. This connected network enables research facility collaboration throughout Europe. Specifically, the extensive living laboratory facilities at Belgium's KU Leuven Energy Institute,[8] focus on the social aspects of integrated energy systems.

Across Europe, the drive to achieve carbon-free energy systems is significant, both as led by policy and with funding from grants. From an engagement perspective, industry is actively involved in projects; however, although energy markets have existed for some time, market reformation is still in its infancy.

Throughout the discussion on Europe, the significance of the social science aspects of understanding human behavior patterns associated with energy use was highlighted, and much still needs to be explored and understood around the interrelationships between energy self-sufficiency, security of supply, and market drivers that impact customer usage patterns.

[3] https://es.catapult.org.uk/
[4] http://pndc.co.uk
[5] http://www.strath.ac.uk/pndc/
[6] https://energy.gov/under-secretary-science-and-energy/grid-modernization-initiative.
[7] https://www.nrel.gov/esif/
[8] http://set.kuleuven.be/ei

The Electric State of The Globe: Discussion Takeaways

- In developing world regions, smart metering is primarily being used as a tool to minimize theft. New electrification techniques are likely to be developed as island solutions and could provide useful insight for developed world solutions.
- The development of technology in China might offer significant insight for the western world, as the technology solutions might be transferable.
- The intervention of market initiatives, new market techniques and social behaviour is likely to be explored over the next 5-10 years through facilities in the United States, United Kingdom, and Europe where policy frameworks driving to a low carbon world are prevalent. Market transformations will accelerate this change further.
- Visibility of research facilities and capability is emerging:
  - In the United States, this being led through some connected efforts by Sandia National Laboratories and will conclude during the next 12 to 18 months.
  - In the United Kingdom, this is being led through some efforts by the Energy Systems Catapult.
  - In Europe, the DER Lab platform provides visibility of facilities available.

It is clear that a rich tapestry of facilities exists and visibility around capability and routes to access will assist with collaboration and integrated utilization of the facilities.

Focused Sessions

Three targeted sessions of the workshop enabled highly interactive, exploratory discussions on how a low-carbon world could be realized:

- Devices and systems integration
- Sensing and measurement
- Communications, cybersecurity, and resilience.

Understanding current activities in these areas that are underway in both the United States and United Kingdom would usefully set the scene for potential collaborations in research, validation, and/or implementation. Key observations following these discussions are documented here.

Devices and Systems Integration

Significant discussions took place on the visibility of the national laboratory infrastructure in the United States and the establishment of an open-access library for models and test procedures. These are seen as key elements to help facilitate device development and an effective means for their integration into smart grid applications. Communications networks were highlighted as being central to the integration challenge. Importantly, the transformation of control from its current application at the center of an electric grid to the network edge was noted as a significant challenge. In the future, it was suggested an electric utility's control room would not control everything anymore; it might control certain aspects, but generally it may only have visibility into the behavior of many distributed, automated systems.

An application project (known as TDI 2.0) is currently being developed in the United Kingdom to address the issue of DERs presenting upstream constraint issues for the National Grid (the transmission system operator). UK Power Networks[9] shared the project's concept, which is to create a regional reactive power market by using distribution-connected DERs. This is an ambitious project that is creating new market models to support a dense penetration of DERs. The benefits of this approach include the potential to enable the connection of a larger number of DER devices without requiring transmission system reinforcement. The project, though still in development, requires a number of devices (DER-based) to provide data and to be intelligently integrated to permit the market (also under development) to operate effectively. Key aspects include forecasting at a regional level, solving optional power flow situations, and effective control algorithms.

Through discussions on this project, significant interest was expressed in sharing future learning outcomes from the United Kingdom with the United States. The project was recognized as ground-breaking in bringing regional power markets to life.

Cisco led a discussion on the capability of infrastructure to enable device integration. Although significant legacy communication infrastructure is presently embedded in electric power networks, the ability to impact future capabilities will require the adoption of multiservice platforms to provide the necessary connectivity and data requirements. The set of solutions clearly needs to address bandwidth, latency, reliability, and security issues. These matters are all addressable, perhaps with evolving technology or by transferring capabilities from other sectors. Concerning effective future architecture models for device integration, some very clear messages were delivered:

- The Internet of Things will be part of the solution set.
- Storage, analysis, and decision-making will need to take place at the network edge instead of at a central control point.
- A solution set of connectivity that focuses on an ecosystem will need to be considered because no single provider will have the solution for all situations.
- Moving from a laboratory environment to a real environment will present a range of risks; however, the laboratory environment being designed and installed at the University of Strathclyde's PNDC provides an ideal platform for integration and control methodologies to be refined prior to network rollout.
- As always, security and resilience will be key aspects to consider; however, these risks can be managed through an appropriate approach.

Sensing and Measurement

Oak Ridge National Laboratory[10] shared an overview of the DOE-funded programs in six key areas associated with sensing and measurement:

- Enhancing distribution system sensing including visualization techniques
- Enhancing transmission system sensing by building on the rich data available following the installation of synchrophasers (i.e., phasor measurement units); in particular, post-event data might be a useful source of information
- Sensing for buildings and end customers geared toward improving utilization and efficiency through the use of secure wireless networks
- Utilizing analytics and visualization techniques at an appropriate level
- Creating a valid communications test network to integrate the data and validate effectiveness

[9]http://www.ukpowernetworks.co.uk/
[10]http://www.ornl.gov/

- Facilitating regional and crosscutting domain capabilities.

A road map is being finalized by DOE with key industry stakeholder involvement for the sensing and measurement activity that includes these six focus areas. Participants noted that in the U.S. environment:

- The range of possibilities for the development of sensors is huge.
- The urgency for sensor development in the U.S. utility market has yet to emerge; it is believed that this will become more significant as the penetration level of DER devices grows exponentially, and market reform might be one of the key drivers for this to occur.
- Clarity is needed from utilities and DER device manufacturers on what is required to be developed.

From the U.K. perspective, the PNDC shared their knowledge of their sensors and measurement roadmaps and indicated an opportunity to collaborate with the United States. There was clear consensus from participants on the ability to develop sensing and measurement techniques and that their connectivity is possible, but many observations were echoed around gaining clarity on what needs to be measured and the level of accuracy that is required.

To emphasise these points, 42 Technology shared their experiences in the development of sensors and reinforced the importance of understanding the customer being served and the communications platform, technology platform, and power source being used as critical aspects that need to be established early on. It was emphasized through practical examples that sensors can be developed and implemented in a relatively short time frame. At this time, the utility sector is on the verge of urgency on this topic, and clarity on what needs to be measured is a key consideration. To a large extent, it was recognized in distribution networks that it might be as simple as measuring basic parameters such as voltage, current, and frequency; however, the pull from the industrial sector has yet to crystallize, and it might occur only when market reform occurs.

Throughout this section, the following topics emerged as areas of potential collaboration:

- Sensing and measurement road map exchange between Oak Ridge National Laboratory and the PNDC
- Comparison of state estimation work between research underway in the United States and United Kingdom
- Sharing the basis of the planned communications test network for the PNDC for international access or emulation.

Communications, Cybersecurity, and Resilience

The third focus session highlighted the possibility that high penetration levels of DER devices might create an exponential requirement for connectivity, to enable the interoperability across localized energy vectors in a safe, resilient, and secure manner. The volume of projected devices at the distribution level presents voltage and cost burdens; however, the economics might be solvable as a consequence of the total shift taking place across the energy value chain.

The main technology challenges relate to:

- Coverage
- Reliability
- Cybersecurity
- Traffic prioritization.

In the United Kingdom, the existing copper cabling in the communications infrastructure is not necessarily scalable to accommodate future needs; however, a range of other viable solutions are readily available. One solution could be the adaptation of a dedicated spectrum in the 400-Mhz region. This spectrum could soon become available and offer the utility sector a baseline that could prove transformative.

In the United States, the efforts being extended to utility-level security and resilience are significant, particularly in the development of standards. Attendees widely recognized that sharing the work around these standards could mutually benefit the United States and the United Kingdom. Interestingly, it seems that the utility sector lags behind other sectors with efforts to mitigate cyber-related threats. This might be, in part, because legacy private transmission lines in the infrastructure provide a layer of protection against potential threats; however, attendees also recognized that this is not likely to continue. Relying on vendors to provide necessary security protection could be enhanced through the application of appropriate standards, but utility companies need to request that these protective measures are put in place.

To illustrate the electric grid's vulnerability to cyber threats, examples were provided that demonstrated potential routes for cyber-attacks to occur. These indicated the importance of system-level protection and also the impact from potential personnel actions that might create a path for a cyber-attack.

Providing a system that is completely secure from cyber-attacks is unrealistic; however, mitigation steps can be taken, and the level of protection specified should be proportionate to the potential risk and impact. Many organizations apply a one-size-fits-all approach without considering the likelihood of impact.

The following issues are significant for further focus:

- Standards development in the United States is leading the way in this area.
- Utilities should be aware of the potential risks and deploy system and personnel protection approaches as appropriate.
- In many ways, other sectors are more advanced than the utility sector when it comes to managing cyber risks.
- The need for utilities to recover from either a malicious or natural event should be rehearsed and practiced, perhaps by using test

Speed Brainstorming Session

To take advantage of the international gathering of experts in the transmission and distribution sectors from academia, industry, and research facilities, participants took the opportunity to conduct three intensive brainstorming sessions. These were designed to collect the most critical ideas for further prioritization and collaboration. The prioritized results are shown below.

Potential International Technology Transfer

This session was geared toward identifying areas where technology that has been deployed or is close to deployment could be leveraged from the United States to the United Kingdom or vice versa. In many areas, complementary activities are taking place, and consequently the opportunity to share and exchange knowledge was a common theme throughout all of these observations. These included:

- Design planning tools and control algorithms that are associated with DERs, microgrids, smart inverters, and back-to-back converters are meaningful areas for further work.
- Sharing best practices for resilience stood out as being significant—particularly as related to weather events that impact flexible and controllable loads, fault-level detection in networks that have high inertia and/or a high penetration of DERs, state estimation, and cybersecurity.
- Energy storage presents many opportunities at both the large and small scale—for understanding the technology, life-cycle management issues, and coordination with other DERs.
- In the area of standards, sharing techniques to run a system closer to design limits, or even to challenge existing design limits in a risk-appropriate way, might offer significant potential to adopt larger amounts of DERs onto networks.

Potential International Laboratory Collaboration

After sharing some of the laboratory capabilities in the United Kingdom, United States, and throughout Europe, participants discussed some steps that could be taken to encourage sharing and cross-utilization. Attendees identified the work being undertaken by Sandia National Laboratories[11] in the United States and by the Energy Systems Catapult in the United Kingdom to create an index of capabilities and to simplify routes to access. These outputs were designed to consider ways to leverage their combined capabilities.

Action items included:

- Create a memorandum of understanding for laboratories to collaborate and clearly address the intellectual property issues that might prevent effective collaboration.
- Create an ability to share laboratory design and safe operating practices for the benefit of all.
- Create a forum of lessons learned around the operations of laboratories.
- Enable data links between labs—perhaps on a per-project basis, but also perhaps on a strategic basis so that a virtual test environment might be created (e.g., for power-hardware-in-the loop or for ease of access to large computational capabilities).
- Replicate experiments at different locations to improve validity and strengthen challenges in the results produced.
- Consider collaborative publications, coordinated responses to funding calls, and researcher exchange programs.

[11] http://www.sandia.gov/

Potential Industrial Partnership Opportunities

A number of opportunities for potential industrial partnerships were discussed, and again participants recognized that outcomes are better leveraged and significantly enhanced when industry needs, academic thinking, and research laboratory capabilities are aligned and focussed on finding or defining potential solutions. The areas below reflect some of this collective thinking.

- Sharing data and analytics can be greatly improved and enhance asset management, DER management systems, and the implementation of augmented reality. This need focuses on specific topics; however, the capability to access to meaningful data was recognized as a significant area for collaboration.
- Collectively identifying the needs and roles of sensing equipment can greatly accelerate effective deployment and enable capabilities. This could be of particular use in creating new local markets that have high penetration levels of DERs.
- Telecommunication solutions need to be led by industry but informed by risk-assessed cybersecurity and resilience testing.
- Developing algorithms for active management across different timescales can be best enacted through a collaborative framework for a range of different devices.
- Possibilities are numerous for joint proposals on research, publications, field trials, and accelerated deployment.

Next Steps

The ability to implement these ideas in the future is a significant challenge, especially given the geographic spread and different special interests of the individuals present; however, it is anticipated that by noting these areas and with the establishment of the relationships that were formed throughout this workshop, individuals will naturally find a point of connection for some of these activities to progress when there is mutual desire for collaboration.

Conclusions and Recommendations

The goals and objectives listed in the introduction of this report have been largely achieved. The openness and transparency of research capabilities coupled with the transparency of matters impacting grid modernization in both the United Kingdom and the United States were professionally discussed and explored. The design of the workshop program and sessions allowed for high-level input from all participants, either through open discussions, question-and-answer sessions, or brainstorming.

The productive nature of the brainstorming sessions provided a comprehensive list of potential actions and areas for further development and progression. Participants reaffirmed that the fundamental physical requirements of how to achieve the balance between supply and demand in the most economic manner is a consistent challenge in the United Kingdom and United States; however, some of the approaches to technology, markets, and the pace of transitioning from large thermal power plants to DERs are at different stages of development in both countries. Both the commonalities and differences added to ideas for future collaboration. In the closing sessions, some of the participants noted that the workshop was one of the most engaging and productive in this topic area spanning academia, industry, and research establishments.

As ever, the big questions are what is next and how will these efforts be taken forward? The following are recommended:

- **Short term (immediate):** Relationships have been formed; these can grow and flourish, and natural collaborations will follow. Some of the brainstorming outputs might help stimulate areas for collaboration.
- **Midterm (6–12 months):** The ambition to jointly publish, share laboratory facilities, exchange researchers, and participate in joint funding should be within grasp.
- **Long Term (12–24 months):** The potential for a second workshop to track developments and revisit areas for collaboration should be considered, reviewed, and implemented. This would follow the pattern undertaken in other government departments between the United States and the United Kingdom.

All attendees and participants are encouraged to take matters forward from this report.

Acknowledgments

The authors gratefully acknowledge the work and efforts by the Houston-based UK Science & Innovation office for facilitating this successful event. In addition, the ability to host this event at NREL's ESIF is greatly appreciated.

All sessions were held at NREL's Energy Systems Integration Facility (ESIF), one of the only megawatt-scale research facilities in the U.S. that enables energy integration studies at full power. More information on the ESIF and its user access program can be found on the back of this brochure.

Appendix – List Of Attendees

Name	Title	Company
Art Anderson	Laboratory Program Manager, Grid Integration	National Renewable Energy Laboratory
John Barnett	Project Leader	National Renewable Energy Laboratory
Baz Basnett	Head of Systems Engineering Technology	Cisco's UK Enterprise Networks
Eric Brown	Head of Innovation	Energy Systems Catapult
Jeremy Carey	Managing Director	42 Technology
Federico Coffele	Senior Knowledge Exchange Fellow	Power Networks Demonstration Centre
Ian Cotton	Professor of High Voltage Technology	The University of Manchester
Johan Driesen	Professor and Member of Board of Directors	KU Lueven Energy Institute, Belgium
Anamika Dubey	Assistant Professor	Washington State University
Carolina Escudero Concha	Power Systems Development Engineer	UK Power Networks
Ella Fejer	Science & Innovation Officer	UK Science & Innovation Network
Lauren George	Head of Science & Innovation	UK Science & Innovation Network
Bryan Hannegan	Associate Laboratory Director, Energy Systems Integration Facility	National Renewable Energy Laboratory
Steve Hauser	CEO	The Gridwise Alliance
Erfan Ibrahim	Director, Center for Cyber-Physical Systems Security & Resilience	National Renewable Energy Laboratory
James Irvine	Reader	University of Strathclyde
Mike Jones	Senior Resource Planner	Platte River Power Authority
Philip Jones	CEO	Northern Powergrid
Andrea Kishne	Centre Administrator	Smart Grid Center, Texas A&M University
Ben Kroposki	Director, Power Systems Engineering Center	National Renewable Energy Laboratory
Matt Lave	Senior Member of Technical Staff	Sandia National Laboratories
Kevin Lynn	Director	DOE Office of Energy Efficiency & Renewable Energy
Iain Miller	Head of Innovation	Northern Power Grid

Name	Title	Company
Rohit Nair	Senior Engineer	PacifiCorp
Graham Oakes	Founder and CEO	Upside Energy Ltd.
Terry Oliver	Chief Technology Innovation Officer	Bonneville Power Administration
Ben Ollis	Research-and-Development Staff	Oak Ridge National Laboratory
Mark O'Malley	Professor of Electrical Engineering	University College Dublin
Haris Patsisos	Lecturer	Newcastle University
Leslie Ponder	Technology Review Manager	Duke Energy
Teresa Ringenbach	Senior Manager of Government & Regulatory Affairs–Midwest	Direct Energy/Centrica
Tom Rizy	Power and Energy Systems Group	Oak Ridge National Laboratory
David Rutherford	CEO	Power Networks Demonstration Centre
Debbie Seidman	Energy Technology Project Manager	Platte River Power Authority
Robert Sherick	Principal Manager	Southern California Edison
Mariko Shirazi	Scientist	National Renewable Energy Laboratory
Julian Stafford	Director–Wireless Strategy	WHP Telecoms
Martha Symko-Davies	Director of Partnerships, Energy Systems Integration	National Renewable Energy Laboratory
Phil Taylor	Professor & Director	Newcastle University
Colin Taylor	Director, Engineering Services	Scottish Power Energy Networks
Juan Torres	Deputy to Vice President E&C Programs	Sandia National Laboratories
Sarah Truitt	Partnership Development, Energy Systems Integration	National Renewable Energy Laboratory
Gavin Walker	Professor	University of Nottingham
Y.C. Zhang	Engineer	National Renewable Energy Laboratory

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