CHAPTER 14
INTEGRATING ENERGY STORAGE – GRID INTERCONNECTION PROCESS AND POLICY

Howard Passell, Charlie Vartanian, Will McNamara, Jeremy Twitchell, Samuel Ojetola, Pramod Kulkarni

Abstract

Energy generation, transmission, distribution, storage, and consumption are undergoing a revolution in the United States and the world. Effective and efficient interconnection of technical components, all evolving at rapid but different rates, is critical to the effective and efficient adoption of the renewable energy and storage technologies that are essential for achieving decarbonization objectives. Many measures can be implemented to streamline interconnection efficiencies. The relatively narrow concept of interconnection as applied to the process for connecting assets to power grids can also be useful for looking across the broader spectrum of stakeholders that are needed to advance the industry and ultimately deliver greater connectivity, communication, and collaboration across legislatures, industry, regulators, jurisdictions, academia, and other stakeholders. This kind of broad interconnection, including technical approaches as well as social and cultural dynamics, is critical to clearing the path toward greater adoption of advanced energy technologies.

Key Terms

Distributed energy resource (DER), EPAct, Federal Energy Regulatory Commission (FERC), interconnection, investor-owned utility (IOU), renewable portfolio standard (RPS)

1. Introduction

Energy generation, delivery, and consumption are undergoing a revolution in the United States and around the world. Generation by utilities and now by end-use customers leading to movement of electricity in multiple directions, and an increasing consumption by retail customers for an ever-changing array of demands, are altering the energy landscape across all energy sectors in ways not seen since the first electric grid was built over 100 years ago. Increasing interaction and coordination across sectors that historically have had relatively low cross-coordination will effectively address the technical interconnection challenges and opportunities that derive from these changes. The magnitude of these changes requires more than just technological innovation and interconnection, but an integrated approach that unites industry, stakeholders, regulatory, jurisdictional, and academic partners.

Distributed energy resources (DERs), energy storage systems (ESSs), advanced grid communications and smart appliances, microgrids, and widely ranging incentives and pricing structures are all changing and developing faster than industry, consumers, and regulators can keep up. The electricity industry as we know it today–including vertically integrated utilities, independent generators, grid operators, wholesale and retail producers, and regulators–has historically been a set of institutions that evolved over the last century with mostly linear and predictable growth in energy supply technologies and demands, little involvement from diverse stakeholders, and with energy flowing in one direction, from generators to customers. Those days have passed.

Energy supply and demand, both in front of and behind the meter, are changing in non-linear and difficult-to-predict ways. The institutions surrounding the electricity industry must actively develop policy, business, and regulatory strategies to evolve as quickly as the energy technologies. Waiting to react to the rapidly changing dynamics will leave these institutions playing catch-up–with negative impacts for customers, generators, and grid reliability and resilience. What is needed now are innovative, proactive, early steps that will have high impact in the future.

Interconnection of technologies is a critical process for ALL grid-connected resources including generation and storage and is an established industry practice that mirrors the mapping of assets and jurisdictions groups. This chapter outlines opportunities for better coordination across all stakeholder groups to improve interconnection policy and practices that would otherwise impede the actual physical connection of ESSs to power systems. This challenge and opportunity illustrate the need to update the technical standards for interconnection, which are discussed in a separate chapter. Interconnection standards, interconnection policy, and the regulatory framework in which it all resides, also need to evolve to avoid interconnection becoming a barrier to continued adoption of grid energy storage. IEEE 1547.9, a guide to using IEEE 1547[1] for the interconnection of energy storage distributed energy resources, is a concrete example of the recognized need for industry action specific to technical standards for interconnection of energy storage. In response to this industry need, the IEEE approved creating this guide. The draft guide has now gone to ballot for approval and publication.[2]

A considerable challenge lies in developing the social, economic, regulatory, and policy-related infrastructure and environments to keep up with rapidly evolving technical advances. Technical challenges certainly remain, and technical experts are focused on them. But innovations now, beyond the purely technical ones, are critical to helping the whole industry advance. This chapter presents innovations related to energy storage but could equally be applied to renewables and grid modernization more broadly.

2. The Role of Policy and Standards

Interconnection rules generally consist of:

1. administrative procedures and technical standards used to evaluate potential impacts associated with interconnecting a generation resource to the electric power system
2. contractual agreements stipulating operational and cost responsibilities between the electric utility and the generation resource owner

These rules generally fall into two groups:

1. interconnection for projects participating in wholesale services
2. interconnection of resources by or for end-user retail customers

These two groups generally address:

1. networked high voltage (69kV and above) transmission
2. radial medium voltage (34KV and below) distribution

[1] https://standards.ieee.org/standard/1547-2018.html
[2] Ballot initiated December 2021. P1547.9 project info is at, https://standards.ieee.org/project/1547_9.html

For wholesale interconnection in the United States, the Federal Energy Regulatory Commission (FERC) Small Generator Interconnection Procedures (SGIP) and Large Generator Interconnection Procedures (LGIP) govern. For retail, the jurisdictional entities that govern retail electric service typically approve retail tariff rules for resource interconnection. One example of a jurisdictional entity approving a tariff rule is retail electric interconnection Tariff Rule 21 that the three investor owner utilities in California use, as approved by the California Public Utilities Commission (CA PUC).

Aggressive renewable portfolio standards (RPSs) adopted by states in recent decades, along with many states establishing commitments to 100 percent clean (i.e., non-carbon based) energy within the last year, have heightened the urgency for the development of good interconnection policy.

In 1983, Iowa became the first state to adopt an RPS. However, it would not be until the 1990s that other states followed (New Jersey–1991, Massachusetts and Nevada–1997, Wisconsin–1998, and Texas–1999). Out of the current 29 states that have an RPS, most did not establish their renewables requirements until the 2000s. Even California, which is considered a leader in renewables policy, did not adopt an RPS until 2002. Furthermore, prior to the early 2000s, few states had any comprehensive procedures for interconnecting distributed generation. Clearly, advances in renewables, storage technologies, and interconnection approaches have matured considerably since the 2000s, but much more remains to be achieved.

Available data indicate that 36 states and the District of Columbia have adopted statewide interconnection standards either in the form of an administrative code or a public utility commission docket/order (see Figure 1). These standards vary widely from state to state but, as noted above, generally consist of: 1) the administrative procedures and technical standards used to evaluate potential impacts associated with interconnecting a generation resource to the electric power system; and 2) contractual agreements stipulating operational and cost responsibilities between the electric utility and the generation resource owner. These standards mainly address interconnection procedural requirements while relying on the technical requirements provided by IEEE standard 1547—*Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces* and Underwriters Laboratories (UL) standard 1741— *Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources*.

However, interconnection standards for distributed generation were historically formulated based on a definition of "generating facilities" that is no longer appropriate as it does not address the unique operating characteristics of energy storage. The inadequacy of these historic interconnection standards has created a barrier for energy storage simply due to the fact that it has created uncertainty about how energy storage should be treated at a localized level, thus resulting in market inertia and delays in permitting.

Figure 1 shows the current interconnection standards adoption status of each US state.

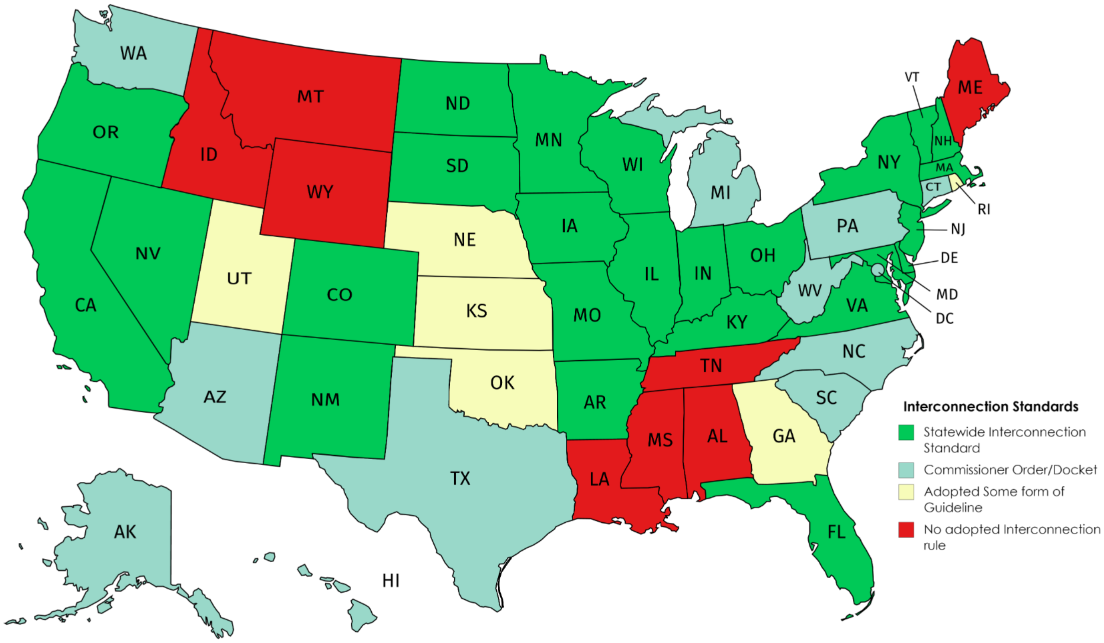

Figure 1. Adoption of interconnection standards

A useful reference for understanding the specific interconnection policies and procedures at state level is the Database of State Incentives for Renewables & Efficiency (DSIRE) Interconnection Policy Database.

Legislation at both the state and federal levels have accelerated the expansion of renewables and energy storage, along with the interconnection standards that enable such technologies to contribute to the grid. At the federal level, the 2005 Energy Policy Act (EPAct) jumpstarted renewables with a tax credit for photovoltaics and solar thermal systems, with amendments later adding credits for wind and geothermal applications. Further, the EPAct defined and required utility provisions for interconnecting privately-owned renewables, and, later, energy storage.

Specifically, the EPAct stated that:

> *Each electric utility shall make available, upon request, interconnection service to any electric consumer that the electric utility serves. For purposes of this paragraph, the term "interconnection service" means service to an electric consumer under which an on-site generating facility on the consumer's premises shall be connected to the local distribution facilities. Interconnection services shall be offered based upon the standards develop by the Institute of Electrical and Electronics Engineers: IEEE Standard 1547 for Interconnecting Distributed Resources with Electric Power Systems, as they may be amended from time to time.*

Thus, the EPAct recommended IEEE 1547 be adopted as a baseline for interconnections by all states. Since the EPAct of 2005, thousands of renewable energy bills have been enacted in state legislatures across the country on topics ranging from tax incentives and financing, to land use and energy system ownership. Dozens of states have adopted renewable portfolio standards, 17 states (as of this writing) and more than 100 cities and counties have adopted 100 percent clean energy or decarbonization standards [1]. These legislative actions have driven significant deployment and adoption of renewables, further increasing the need for streamlined and effective interconnection rules.

Section 1254 of the EPAct required that states (and nonregulated utilities) begin to consider development of interconnection standards based on IEEE 1547 with deadlines for completion in the subsequent two years. In the years since many states took those initial steps to develop interconnection standards, energy sector technologies have rapidly evolved (including expanding deployments and declining costs in energy storage), and yet most states have not revised their interconnection standards to specifically consider energy storage.

Over the past two decades, five models for interconnection standards have emerged as templates or "blueprints" for how states can structure their own standards. The five models are:

- California Public Utility Commission Rule 21 Interconnection: Contains two approaches that have subsequently become standard operations – 1) screening processes for streamlined review of interconnection applications, and 2) procedural timelines for expedited interconnection processes.
- The Mid-Atlantic Distributed Resources Initiative (MADRI): Seeks to identify and remedy retail and wholesale market barriers to the deployment of distributed generation, demand response, energy efficiency and energy storage in the Mid-Atlantic region.
- Interstate Renewable Energy Council (IREC) Model Interconnection Procedures: Reflects the latest evolution in best practices to facilitate higher penetrations of distributed energy resources (DERs) on the grid, integrating new technologies while maintaining grid safety and reliability.
- Bonneville Power Administration (BPA) Small Generator Interconnection Procedures: Provides the procedural framework for moving from a submitted Interconnection Request to a completed interconnection for generators of 20 MW or less (nameplate).
- IEEE 1547-2018 - IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces: Addresses the technical specifications for, and testing of, the interconnection and interoperability between utility electric power systems (EPSs) and DERs. It provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. Most states that have revised their interconnection standards within the last several years have adopted, referenced, or used 1547 in their own rules.

These five models address what might be considered interconnection procedure baselines, along with other commonalities. All five models:

- apply to all DER technologies (not just renewables)
- include simplified procedures for small, residential installations and fast-track procedures for systems less than 2 MW
- provide guidelines for the study of large and more complex systems.

That five different interconnection models exist, written over the course of almost a quarter century and applied in disparate states, is an indication of the inconsistency that exists in the world of interconnection and the relative immaturity of the field. A single national interconnection model may never be appropriate given varying geographic, topographic, social, economic, and political conditions around the country. But a single model with variations to account for differences in region, scale, and technologies would reduce costs, increase efficiencies, and streamline broader adoption of storage and renewables.

3. Current Challenges

Even though energy storage is expected to play a critical role at all levels of the electric system – from utility-scale installations to residential customer applications – the technology is so nascent that most existing interconnection standards at the state level either do not address storage at all or approach it in such a way that limits the full potential of services and benefits that storage can bring to the grid.

While some legacy interconnection standards may be broad enough to cover new and evolving technologies, others completely ignore storage technologies because their standards apply only to "generation sources." Storage can serve as both generation and load, depending on how it is being used at any given moment. A regulatory conundrum quickly develops when a storage installation is capable of acting as both load and generation, with cost allocation being a particularly thorny issue. Typically, cost recovery through rates has been an option for new load facilities, but usually generators have been responsible for their own interconnection costs. Additionally, storage may or may not be allowed to participate in wholesale markets, and the services it can provide in wholesale markets may be restricted. The installation of energy storage and solar together ("solar + storage" or "hybrid systems") further complicates interconnection scenarios.

In fact, the current taxonomy that considers energy storage as both generation and load is arguably an obstacle to streamlined codes and standards, and an example of trying to fit a round peg into a square hole – or into two square holes, in this case. Categorizing ES as its own technology with all its own characteristics may be one of the best ways to resolve some interconnection policy problems.

Another challenge that storage creates relates to "maximum capacity" limits that have been commonplace in legacy interconnection standards. Traditionally, in vetting a DER project and its intent to connect to the grid, a utility would evaluate effects on the system based on the "maximum capacity" of electricity that a particular DER project is capable of supplying the grid. This approach is not appropriate when considering storage technologies because most storage technologies may never provide maximum capacity to the grid but rather be dispatched on an as-needed basis. FERC's SGIP addresses this by directing utilities to assume less than the maximum capacity if a storage technology can limit its export and not impact the reliability of the grid.

Another grey area that can impact the revision of legacy interconnection standards can be ambiguities regarding utility ownership of storage assets. In New York, for example, utility ownership of DER assets (including storage) is prohibited except in limited circumstances. Other states have not addressed ownership issues at all.

Nevertheless, given that interconnection is a critical step for any resource that operates while connected to a utility's grid, standards that preceded the recent and rapid expansion of renewables and energy storage technologies likely need revision. The legacy rules may only apply to generating facilities, largely ignoring or not considering the various roles—including generation, load, transmission, and distribution—that energy storage can play on the grid. Also, the legacy standards may have significant gaps such as:

- applying only to net metered systems or systems owned by residential customers
- being a utility-specific standard
- not applying appropriately to either municipal utilities or electric cooperatives in the state (utility-by-utility for municipals as opposed to a statewide standards for investor-owned utilities [IOUs])

Moreover, interconnection standards can be integrated with other policies addressing decarbonization, distribution planning, integrated resource planning, energy efficiency, etc., to support a comprehensive clean energy plan. A challenge in the updating process will likely come from the fact that energy storage technologies remain very nascent (i.e., immature, still subject to research and development, and not often in widespread use. This means that it may be difficult to ensure that address the full potential of services and benefits that energy storage technologies can bring to the grid.

4. Policy Drivers

Top-down federal policies have been essential for laying the foundation for the adoption of renewables and energy storage and for streamlining interconnection, Federal Energy Regulatory Commission (FERC) Order 888, "Promoting Wholesale Competition Through Open Access Non-discriminatory Transmission Services…" began the crafting of policy for open and non-discriminatory processes for the interconnection of resources with wholesale jurisdictional transmission systems.

Since then, further federal policy has driven industry adoption of renewable resources and energy storage. Specifically, FERC has helped promote the successful and aggressive adoption of advanced technologies into the U.S. industry and power grids. FERC Order 755, enacted in 2011, increased the pay for fast responding sources (i.e., batteries and flywheels) when bidding into frequency regulation markets, and was touted as jumpstarting grid scale batteries. FERC Orders 784, 792, 845, and particularly 841, followed suit and further enabled grid scale storage. FERC Order 841 directs ISOs and RTOs to come up with rules to open up their wholesale energy, capacity and ancillary services markets to energy storage resources on a nondiscriminatory basis [2]. [4,5] California promptly adopted its energy storage mandate in 2013, and since then 14 other states have written energy storage policies aimed at encouraging adoption or reducing barriers [3]. FERC Order 2222, requiring RTOs and ISOs to accommodate aggregations of distributed ES, further complicates interconnection challenges.

Despite all these advancements, more actions at national, federal, and state levels can lead to further progress.

Relevant actions needed at the national and federal levels include:

- Utilities and other entities conforming to IEEE P2800 for transmission connected resources and IEEE 1547-2018 for DERs. For example, to the extent feasible, ride through curves should be consistent between the two standards.
- Relevant entities should conform to Open Access Transmission Tariff (OATT) Pro Forma Tariff technical processes. For example, Small Generator Interconnection Procedures (SGIP) should be consistent with IEEE 1547-2018.
- Revising IEEE 1547 to address advanced DER interconnections, interoperability requirements, transmission-level interconnections, and distribution connections.
- Determining when federal and/or state interconnection agreements are needed. When a developer seeks to interconnect a storage system to a distribution grid with the intention of participating in a wholesale energy market, it is not always clear if a federal or state interconnection (or both) is required.

Relevant actions needed at the state level include:

- Adopting DER Interconnection Standard 1547-2018 consistently across states. This will support common design and component use, and the ability to assure certified performance. For example, UL 1741 should consistently be used to certify inverters to IEEE 1547 performance requirements.
- Revising existing or legacy state-level standards to ensure applicability to energy storage specifically, including multiple services for storage (at minimum addressing storage as a generation source and load source).
- Developing rules for exporting, non-exporting, and limited exporting storage technologies.
- Sharing best practices especially from high renewables penetration markets (e.g., California Rule 21 and Hawaii Rule 14H).
- Consider revising "maximum capacity" evaluations to address storage systems that may export far less energy to the grid than indicated by the aggregate nameplate capacity of the system.
- Correlating state-level interconnection standards with broader state efforts revising related policies covering net metering, distribution planning, integrated resource planning, and energy efficiency.

These national and state actions provide the broad outline for adoption and interconnection of new technologies, but gaps remain that must be filled with innovative R&D, business, and regulatory approaches.

5. Other Areas for Improvement

One clear avenue for improvement, as demand for renewables continues to grow and the penetration of renewables and storage technologies increases, is to speed up the standards development and review processes. For example, IEEE 1547 was initiated in 1999, was approved in 2003, and revised in 2018. The length of time in between these revisions may have been appropriate given the advance of technologies, but going forward, revisions must occur more frequently to accommodate the speed of technology advances.

There are several ways that the pace of revisions can be increased. One specific way is to maintain active Standards Development Working Groups after revisions are published, versus retiring these teams until the next update. In the case of IEEE 1547-2018, the leadership team is still active with the support of IEEE. The mission of the leadership team is to 1) facilitate the writing of guides, including an active effort to write a guide for the interconnection of DER Energy Storage, and 2) promote industry education on the significant changes in IEEE 1547-2018, including new requirements for DER to ride through grid disturbances, and 3) provide VAR/voltage support.

Another area for improvement addresses the technical interconnection between renewables, storage, and the grid, which is hampered by components that often do not interconnect in a seamless way. Technical interconnection standards just for connecting PV panels to inverters, or inverters to batteries would help streamline installation processes and lower costs.

Cybersecurity is a critical interconnection-related threat. Many of the interconnected DERs, including small ones behind-the-meter, will soon communicate with their utilities for possible dispatch and participate in the wholesale markets. Unless secured, these communications links are vulnerable to cyber-attacks, endangering the connected electrical grid. Though the main purpose of interconnection standards is to ensure that the connected DERs do not compromise the electrical integrity and safety of the connected circuit, however standards must also address the increasing risk of cyber-attacks. Increasingly, engineering specifications that thwart cyber-attacks are folded into the electrical interconnection standards. For example, now California Rule 21 requires that, by default, Distributed Energy Resources within Investor-Owned Utilities (IOU) must utilize the IEEE2030.5-2018 networking standards.

Streamlining those, and many other processes and standards requires greater communication across all stakeholders. Manufacturers, the public, utilities, policymakers, developers, regulators, academia, and the U.S. government R&D community, all have different expertise, different needs, and different expectations. They are all crucial to developing the best practices and standards, but they are stove piped and separated, with few established mechanisms or channels for collaborating and communicating.

The challenge of integrating expertise across disciplines and sectors was tackled for the field of energy storage safety with the Energy Storage Safety Collaborative, developed as a platform to advance stakeholder engagement on safety and reliability codes and standards. This same approach could be applied to many other topics associated with connecting renewables, storage, and the grid. Other groups like this could help establish greater collaboration, communication, and integration across all DER and energy storage interconnection stakeholders.

Interestingly, IOUs deliver ~80% of electricity to US consumers but include fewer than a third of the ~3,300 overall utilities. Public regulatory commissions have jurisdiction over the IOUs but the remainder do not fall under public regulatory commissions and include regional co-ops, municipal utilities, and public utility districts.

Many utilities work under different authorities, and many have divergent policy, finance, and regulatory structures. At the national level, all these utilities work as widely distributed, self-organized complex systems, and deliver electricity to users in a remarkably reliable way. But it is actually an ad hoc assembly of institutions shaped more by historical accident than by intention, both inefficient and ripe for improvement. In the end, the consumer pays for any inefficiencies. As technological innovation accelerates, the current fragmented nature of the industry will weaken the system overall, disadvantage users, and slow the transition to a reliable and resilient 21st century grid.

This is not to say that complete homogenization across all these entities is the answer, but greater standardization, communication, collaboration, and consistency–that is, greater interconnection–is needed to empower industry growth. The National Association of Regulatory Utility Commissioners (NARUC) and the National Rural Electric Cooperative Association (NRECA) help create the kind of collaboration and consistency needed now and in the future. With a heightened level of awareness of the importance of these issues, and expanding engagement across industry communities (e.g., regulatory groups and standard development organizations), energy storage can be better positioned to meet the growing consumer demand and adapt to technological advances.

Another area ripe for improvement is in the public regulatory commissions themselves. The regulatory commission model is one that developed over the last century or so as the electricity industry evolved relatively slowly and in a mostly linear way, with energy flowing in one direction (from utility to customer), with relatively little input from advocacy groups or other citizens, and with relatively few major technology disruptions along the way.

Now the electric industry is evolving rapidly, electricity is moving in multiple directions, external experts and other advocates are increasingly involved in regulatory business, and major new technology disruptions are occurring regularly in the energy marketplace. Arguably, the public regulatory commission model that worked for so long in the past is no longer suited for meeting the current challenges. This is not a criticism of regulatory commissions themselves, which in general, across the U.S., are understaffed, underfunded, and overworked. Regulatory commission staff, who are often generalists who must work on a wide array of regulatory issues across electricity, water, gas, and transportation issues, and who must deal with a complex mix of state, interstate, and national statutes and regulations, can be out gunned by technical experts, attorneys, and other advocates and special interest groups.

Measures that can help improve regulatory processes include the following:

- Increasing states' funding for regulatory commissions
- Expanding the number of staff with special technical and legal expertise
- Requiring that commissioners have or gain technical or legal expertise
- Increasing the number of commissioners to widen the array of expertise

Finally, electrical engineering students must be exposed to a broader, more holistic view of the electrical energy industry and systems. Degrees in these fields require years of study and work on tightly focused, technical topics. In this way, the field itself encourages the silos and stove piping that develop in industry, which can interfere with some of the innovations described in this chapter.

Current criteria for accrediting academic engineering programs includes language that already addresses these needs. Some of those criteria are shown below. Among others, students must show abilities to:

- Apply engineering design to solve issues involving public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
- Communicate effectively with a range of audiences.
- Recognize ethical and professional responsibilities and make informed judgments which consider the impact of engineering in global, economic, environmental, and societal contexts.

These are laudable goals and some in the field would argue that they are already sufficiently well met. But perhaps even greater success could be found by industry working more closely with academia to ensure students excel in an increasingly complex and multidisciplinary engineering, legal, and regulatory environment.

With all this in mind, seamless interconnection becomes a challenge much greater than just a technical engineering one. It becomes a challenge of interconnecting technical and legal skills with policy, economic, and even social and political knowledge and insight.

6. Concluding Remarks

New technologies in energy generation, delivery, and consumption are advancing at a rapid pace and standards and policy have not kept up. And yet, advancing the pace of development of new standards and policy is critical to maintaining the pace of technological advance. Federal and state legislation has laid the foundation for technological advance, but gaps remain – some to be filled with more legislation, and some to be filled with innovative academic-, industrial-, and policy-level innovation. Speeding up the processes for developing and revising standards, eliminating silos and stovepipes, and encouraging greater communication and collaboration across disciplines, reforming the regulatory commission model, and educating electrical engineers to see beyond narrow technical horizons are innovations that will help pave our way into the future.

Howard Passell works in the Energy Storage Systems Department at Sandia National Laboratories (Sandia) in Albuquerque, New Mexico. His work focuses on energy storage, grid modernization, energy security, and decarbonization. Over 23 years at Sandia he has worked on energy and water resource monitoring, modeling, management, capacity building, and policy-related projects at various scales in the United States, Central Asia, the Middle East, and North Africa. This included helping to lead Sandia's efforts in DOE's Solar America Cities initiative and developing energy conservation software and methodology for large institutions. He has worked on emerging national security issues associated with energy, water, food, ecosystems, and population, with an emphasis on the relationships between resource scarcity and human security. He earned master's and doctorate degrees in conservation biology and hydrogeoecology at the University of New Mexico. His undergraduate studies were in classical literature and the liberal arts at St. John's College in Santa Fe, NM and The Ohio State University in Columbus, Ohio.

Charlie Vartanian is a Technical Advisor at the Pacific Northwest National Laboratory where he focuses on integration of energy storage with power systems. Charlie has 25 years of industry experience deploying advanced grid technologies, performing system studies, and contributing to standards development. Prior employers include Mitsubishi Electric, the California Energy Commission, and Southern California Edison. During his 15 years at SCE, his activities ranged from T&D planning through grid R&D.

Will McNamara serves as Grid Energy Storage Policy Analyst for Sandia National Laboratories with a focus on energy storage policy development at the federal and state levels. Will has spent his entire 23-year career in the energy and utilities industry with a concentration on regulatory and legislative policy. He has served as a lobbyist in California and has represented major utilities across the United States in numerous jurisdictions in proceedings pertaining to integrated resource planning, procurement, cost recovery, rate design, and the development of policymaking best practices. Will's areas of subject matter expertise, in addition to energy storage policy, include distributed energy resources, AMI/smart grid, renewables, and competitive retail markets.

Jeremy Twitchell is an energy research analyst at the Pacific Northwest National Laboratory, where he leads the equitable regulatory environment area of the PNNL Energy Storage Program and assists in distribution system planning research. In those roles, he is responsible for reaching out to states to provide technical assistance in analyzing energy storage and other developing energy resources and incorporating them into utility planning and procurement activities. Prior to joining PNNL, Jeremy spent five years at the Washington Utilities and Transportation Commission, where he was the staff lead for the development of policies associated with the treatment of energy storage in utility resource planning and rulemaking. His work has supported integrated resource planning, which included development of a distribution planning rule. He participated in multiple utility advisory groups on energy efficiency and resource planning, provided expert testimony in the areas of rate design and resource acquisition, and oversaw renewable resource portfolio standard compliance.

Dr. Samuel T. Ojetola is a senior member of the technical staff in the Electrical Power System research department at Sandia National Laboratories, Albuquerque, NM. He completed his BS in electrical and electronics engineering at the University of Lagos, Nigeria, his MS in electrical engineering at the University of Bridgeport, CT and his PhD in electrical engineering at Montana State University, Bozeman, MT. His research interests include power system dynamics and control, renewable energy integration and wide area measurement systems.

Pramod Kulkarni is a Senior Advisor at the Customized Energy Solutions' (CES) Emerging Technologies Group since 2013. CES facilitates participation of fossil fuel and renewable electric generators, demand-response and energy storage in the wholesale markets in the US and Canada. Pramod analyzes regulations, technologies and markets for energy storage. He advises clients on market opportunities, regulatory impacts, performance characteristics, use-cases and associated economics for storage technologies and microgrids. Prior to working at the CES, Pramod worked at the California Energy Commission for 22 years and started and managed the energy storage program at the Energy Commission. Pramod has been a US DOE's Energy Storage Program Peer Reviewer since 1996 and has contributed to DOE's past editions of Energy Storage Handbook.

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