U.S. DEPARTMENT OF ENERGY

Obstacles And Opportunities for Information and Operation Technology Modernization By Regulated Utilities

Report to Congress
August 2023

United States Department of Energy
Washington, DC 20585

Message from the Director

The cost-of-service (utility ratemaking) model is currently the primary funding source for regulated utilities outside the state and Federal assistance. This model is crucial in financing Information Technology (IT) and Operational Technology (OT) modernization to improve efficiency, security, resiliency, and reliability. However, this regulatory construct can pose a challenge for electric utility providers looking to make significant investments in IT and OT to accelerate the integration of renewable energy sources, energy storage, transportation, and building electrification to meet the nation's decarbonization goals.

To achieve these goals, IT and OT modernization investments may require a combination of different funding models, financing options, and/or Federal assistance. The traditional cost-of-service model may face opposition from customers and regulators concerned about rate increases. Depending on local policymakers' priorities, IT and OT modernization may not be recoverable through rates charged to customers or may not be a priority.

The Infrastructure Investment and Jobs Act (IIJA) presents a historic opportunity for the Department to deliver resilient, reliable, flexible, secure, sustainable, and affordable electricity. To keep this momentum, it is essential to explore alternative funding models and financing options to accelerate IT and OT modernization, in addition to the traditional cost-of-service model. This will enable electric utility providers to integrate renewable energy sources, energy storage, transportation, and building electrification more swiftly to achieve the nation's decarbonization goals.

Pursuant to statutory requirements, this report is being provided to the following Members of Congress:

- **The Honorable Kay Granger**
  Chairwoman, House Committee on Appropriations
- **The Honorable Rosa L. DeLauro**
  Ranking Member, House Committee on Appropriations
- **The Honorable Chuck Fleischman**
  Chair, House Subcommittee on Energy and Water Development, and Related Agencies, House Committee on Appropriations
- **The Honorable Marcy Kaptur**
  Ranking Member, House Subcommittee on Energy and Water Development, and Related Agencies, House Committee on Appropriations

If you have any questions or need additional information, please contact me or Ms. Katie Donley, Director, Office of Budget, Office of the Chief Financial Officer, at (202) 586-0176.

Sincerely,

MARIA ROBINSON

Digitally signed by MARIA ROBINSON
Date: 2023.09.07 16:43:16 -04'00'

Maria D. Robinson
Director
Grid Deployment Office

Executive Summary

Safe, secure, and reliable power grid is an essential backbone for the American economy. In 2009, the American Recovery and Reinvestment Act (ARRA) provided significant funding for securing and updating various grid components. On November 15, 2021, the bipartisan IIJA was signed into law, marking a historic investment towards a cleaner energy future for America. The IIJA focuses on developing and showcasing new technologies, streamlining permitting procedures, and implementing significant improvements to our electricity infrastructure.

The U.S. electricity grid requires IT and OT enhancements to keep up with modern technologies, market dynamics, and consumer preferences. However, adopting new technologies, such as smart appliances, building, and transportation electrification, integrating renewable energy, and grid optimization solutions, is happening faster than the regulatory process. Policymakers must develop policies and regulations that support cost-effective investment while enabling innovative technologies to thrive in a rapidly evolving environment. Reframing cost recovery for IT and OT involves treating these expenses as capital investments rather than operational costs, as has been done historically. Such an approach recognizes the long-term benefits that IT and OT systems can bring to the power grid, including increased efficiency, affordability, reliability, and resilience. However, since the shelf life of IT and OT systems can be relatively short due to rapidly evolving security threats, it is advisable to avoid recovering their costs over extended periods. This allows for timely system upgrades and security measures implementation, thus reducing the risks and ensuring the power grid's long-term reliability and security.

Furthermore, significant infrastructure upgrades are necessary to meet the demands of a changing grid network. IT and OT enhancements will accelerate the integration of distributed energy resources, improve wholesale market operations, increase resilience, and deliver renewable energy from remote locations to urban areas. Given the reliance on IT and OT technology, cybersecurity and secure communication have become increasingly vital for any initiatives to modernize and upgrade the power grid.

Additionally, the distribution system will need more investment as more customers deploy distributed energy resources (DERs). A more flexible system will require a much more adaptable and technologically advanced distribution grid. In addition, state focus on grid modernization will drive even more IT and OT innovation to meet targets especially for the distribution system. This report aims to explore the obstacles and opportunities for wide-scale adoption of emerging and existing IT/OT solutions that could assist policymakers in their efforts to gain a deeper understanding of the many components of grid modernization and provide a foundational knowledge of these issues and a platform of understanding upon which they can build to accelerate IT and OT modernization.

OBSTACLES AND OPPORTUNITIES FOR INFORMATION AND OPERATIONAL TECHNOLOGY MODERNIZATION BY REGULATED UTILITIES

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I. Legislative Language

This report responds to a Congressional request set forth in H. Rept. 117-394, accompanying the House Energy and Water Development and Related Agencies Appropriations Bill, 2023, H.R. 8255, wherein it is stated:

> *"Wide scale adoption of emerging and existing digital technology solutions may assist regulated utilities in the registration, scheduling, dispatch/activation, measurement/verification, and financial settlement of energy customers and their devices. The Department is directed to provide to the Committee not later than 180 days after enactment of this Act a report that explores the obstacles and opportunities for adoption of information technology modernization technologies by utilities bound by the current cost-of-service regulatory model. Further, the report shall include the current treatment of the adoption of such technologies in rate recovery."*

II. Introduction

The electricity system is undergoing rapid transformation driven by the electrification of large segments of the economy including the transportation and the building sectors. This transformation is also driven by the decentralization of the industry caused by the increased penetration of inverter-based resources (IBRs), such as energy storage, inverter-based generation in the transmission system, and the growing number of DERs. Additionally, the modernization of IT and OT through the implementation of smart metering, automation, smart sensors, and other digital network technologies, as well as the integration of smart connected end-user devices, has further facilitated this transformation. These modernization efforts enable real-time optimization of production and consumption, making it easier to ensure system stability and seamless operations while allowing for better interaction with customers.

A significant challenge to adopting these grid modernization digital technologies is that the current regulatory paradigm may need to recognize their full economic value to the system. This report examines the regulatory paradigm and what challenges and opportunities exist in IT and OT modernization that supports the full evolution of the grid. Both policymakers and customers recognize there is a new paradigm of two-way electricity flow. This paradigm is being facilitated by the increasing use of DERs; IT and OT modernization, which enables two-way information flow; and the adoption of decentralized operation enabled by emerging technologies. These changes are already present within the grid or will soon be upon us.

This report responds to the congressional request set forth in H. Rept. 117-394, accompanying the House Energy and Water Development and Related Agencies Appropriations Bill, 2023, H.R. 8255, requesting information on the current treatment of emerging digital technologies that support the modernization of the grid, as well as obstacles and opportunities facing the adoption of ITIT modernization by utilities that operate under the cost-of-service regulatory model.[1]

III. Modernization and Digital Technologies

IT and OT are the key elements of the digitization of the grid. The IT side encompasses business applications and enterprise functions (i.e., billing, accounting, customer service, etc.), but also smart grid digitalization, including real-time data collection, enhanced automation, and data analytics. OT platforms have historically been associated with maintenance scheduling, keeping track of assets, electronic format equipment manuals, etc. Like IT, the OT also requires real-time data analysis. Modern OT platforms power sophisticated asset management systems, and control systems.[2] The convergence of IT and OT is crucial for improving efficiency, reliability, and resilience. Collaboration between IT and OT teams are needed for a holistic approach that integrates IT and OT systems, people, processes, and technology. Benefits include improved situational awareness, control, automation, and data analytics. This aligns with integration of renewable energy sources, energy storage, transportation, and building electrification to meet the nation's decarbonization goals.

This section introduces key IT and OT modernization concepts in relation to the electric utility industry. First, it describes IT and provides an overview of IT modernization technologies. Second, it describes OT and modernization technologies. Finally, it describes the convergence of IT and OT modernization technologies.

A. Information Technology

IT, in the context of this report, refers to the computer-based systems and software used to manage and support the business operations of a utility, such as financial management, customer service, and human resources. IT systems also include technologies used to manage and analyze data related to energy usage, grid performance, and customer behavior. The following are examples of IT modernization technologies that electric utilities can implement.

- **Asset Management Systems (AMS)**: AMS is used to manage the physical assets of the power grid, including transmission lines, substations, transformers, and other equipment. AMS helps utilities track their assets' location, status, and condition, schedule maintenance and repairs, and plan upgrades and replacements.
- **Customer Information Systems (CIS)**: CIS is an IT system that stores and manages customer data, including billing and payment information, account details, and service

[1] The Energy and Water Development and Related Agencies Appropriations Bill, 2023, Report 117-394. H.R. 8255, p.131

[2] "Smart Grid System Report." Reports and Other Documents. November 28, 2018. https:/www.energy.gov/oe/articles/2018-smart-grid-system-report, p.14

requests. CIS is used to manage customer interactions and ensure accurate and timely billing.

- **Customer Relationship Management (CRM)** systems enable utilities to manage customer interactions more effectively, improving customer satisfaction and reducing the workload of customer service staff.[3]
- **Cybersecurity systems** help utilities protect their IT infrastructure and data from cyber threats. Cybersecurity is becoming an increasingly important area of focus as utilities become more reliant on IT systems.
- **Data analytics and visualization tools** help utilities analyze large amounts of data more effectively, identifying patterns and trends that can inform decision-making and improve system performance.
- **Enterprise Resource Planning (ERP)** systems enable utilities to integrate and streamline their business processes, reducing costs and improving operational efficiency.
- **Geographic Information Systems (GIS)** help utilities manage and analyze data related to the physical assets of the grid, such as transformers, poles, and wires, which helps improve the accuracy and efficiency of maintenance and repair activities.[4]
- **Smart Metering (SM) and Advanced Metering Infrastructure (AMI**) technology refers to the measurement and collection system that includes customer site meters, communication networks between the customer and the service provider, and data reception and management systems that make the information available to the service provider and the customer. AMI enables utilities to collect real-time data on energy usage and track energy flows across the power grid. By leveraging AMI technology, utilities can gain insights into energy demand patterns, identify areas of inefficiency, and optimize energy distribution, resulting in reduced energy waste and improved system performance. SM and AMI also facilitate a range of back-end support that can leverage the data including outage notification, demand response, call center optimization, billing processes, and service connection management.[5]

B. Operation Technology

Although closely related to IT, in the context of this report, OT refers to the computer-based systems and software used to control and monitor the physical assets and operations of the electric grid, such as generation, transmission, and distribution equipment. Examples of OT systems used in the electric utility industry include energy management systems, substation automation systems, and distribution automation systems.

[3] "Modern Distribution Grid Volume 1." Pacific Northwest Nation Laboratory. March 27, 2017. https://gridarchitectur.pnnl.gov/media/Modern-Distribution-Grid_Volume-I_v1_1.pdf, p.9

[4] "Modern Distribution Grid Decision Guide Volume III." Pacific Northwest Nation Laboratory. June 28, 2017. https://gridarchitecture.pnnl.gov/media/Modern-Distribution-Grid-Volume-III.pdf, p.8

[5] "Smart Grid System Report." p.27-28

- **Distribution Automation technologies** allow utilities to collect, analyze, and optimize data to improve the operational efficiency of its distributed power system. These technologies include sensors, processors, and communication networks. Distributed automation can improve the speed and accuracy of distribution systems processes including fault location, isolation, and service restoration (aka **FLISR** systems); outage management; voltage control and monitoring; and preventive equipment maintenance.
- **Distributed Energy Resources Management Systems (DERMS)** is a software platform that allows utilities to manage DER, such as rooftop solar panels and behind-the-meter battery storage, to provide grid services and balance energy demand with supply. DERMS uses advanced machine learning-based artificial intelligence (AI) to manage energy resources. DERMS provides real-time visibility into the status of DERs and allows distribution utilities to have the control and flexibility to more effectively manage the technical challenges created by DERs.
- **Energy Management Systems** are software tools that monitor, analyze, and control energy use and system performance.
- **Intelligent Electronic Devices (IEDs)** are advanced technologies that enable two-way communication with devices on a utility's network. These devices gather and share real-time data to create situational awareness of the current state of the grid and allow for localized operational improvements and faster outage detection.
- **Outage Management System (OMS)** is software that models a utility's network for safe and efficient field operations related to outage restoration. OMS is integrated into distribution-level call centers to provide accurate, timely, and customer-specific outage information.
- **Protective Relays** are devices that are used to detect and isolate faults in the power grid. They are responsible for protecting equipment from damage and ensuring the safety of workers and the public. Protective relays use sensors and logic to detect abnormal conditions and trigger the appropriate response to isolate and mitigate the fault.
- **Substation automation** uses data from IEDs to control and automate capabilities within a substation along with control commands from remote users to control power system devices.
- **Supervisory Control and Data Acquisition (SCADA)** are process control systems used to monitor, gather, and analyze real-time data on the electric grid. SCADA can monitor and make slight alternations to function optimally with little human oversight. SCADA systems tend to be precursors to and foundational for the other OT systems defined in this list.[6]

C. Convergence of IT and OT

The continued convergence of IT and OT has a transformative impact on the industrial landscape, leading to productivity, safety, and sustainability improvements. Modernizing

[6] "Modern Distribution Grid Volume I: Customer and State Policy Driven Functionality." Pacific Northwest National Laboratory. March 27, 2017. https://gridarchitecture.pnnl.gov/media/Modern-Distribution-Grid_Volume-I_v1_1.pdf, p. 9-10

measurement and verification processes through OT can help utilities more accurately measure energy use and identify opportunities for energy savings and system improvements. Potential benefits of modernization span multiple areas: Utilizing scheduling processes though IT enables utilities to effectively manage energy supply and demand, particularly when there is a high degree of variability in energy generation from renewable sources. By using advanced forecasting techniques and real-time monitoring, utilities can more accurately predict energy demand and adjust their operations accordingly, which can help reduce costs and improve system reliability. Additionally, utilities can use dispatch and activation processes to respond to outages and other disruptions quickly and efficiently in the energy system. By using advanced analytics and monitoring tools, utilities can more easily identify and resolve issues, as well as coordinate their response with other utilities and emergency response agencies. As energy resources diversify in technical characteristics, functional capabilities, scale, and interconnection location throughout the physical grid, measurement and observability allows grid operators to manage away from contingencies (failures) and toward resilient operational conditions while optimizing for a range of system priorities, including minimizing the economic and environmental costs of service. System observability can enable detection of cyber-intrusion when device or system behaviors deviate from expected performance. Registration processes can help utilities more easily track and manage customer accounts, as well as ensure that customers are accurately billed for their energy use. This can reduce errors and improve the customer experience while also allowing utilities to target their marketing and outreach efforts more effectively.

IV. Current Regulatory Models

Modernizing the power grid requires significant upgrades to the infrastructure, technology, and management systems that enable the generation, transmission, and distribution of electricity. Modernizing the power grid often involves integrating a wide range of new technologies, such as advanced sensors, communication systems, and control software that are complex and challenging to implement. The integration of inverter-based renewable energy sources can also benefit from a modernized power grid, as these sources' sophisticated control systems can utilize advanced contributions to system operations from IBRs. Upgrading or replacing aging infrastructure, implementing new technology, and integrating new renewable energy sources can require substantial investment, and outdated regulations and policies that do not allow recovery may hinder progress.

Traditional regulation poses challenges for utilities seeking to recover these costs from customers. Traditional regulation, also known as cost-of-service (COS) regulation, is the purview of state economic regulators—Public Utility Commissions (PUCs) or Public Service Commissions (PSCs). Regulators use COS regulation to determine the amount of revenue a utility should be allowed to collect from customers to cover the costs of providing electricity and maintaining critical system infrastructure. Costs may include the capital investments and operation and maintenance (O&M) expenses associated with generating, transmitting, and distributing electricity. Maximizing the rate base through capital projects, utilities can increase their potential revenue. The allowed Return on Investment (ROI) allows them to earn a percentage return on their capital projects. Capital investments must be considered "prudent" and "used-and-useful" and generally require PUC approval to earn a reasonable rate of return or profit.[7] Typically, the regulator sets a utility's rates through a "rate case," which is undertaken on a multi-year schedule determined by state policymakers. While rate changes can be requested at any time, they can require substantial effort and a fully litigated investigation of a proposed rate change can take several months. Under a cost-of-service (COS) structure, regulated utilities must actively work to decouple their incentives from raising rates or maximizing electricity sales. Instead, they should prioritize efficiency, conservation, and sustainable practices to ensure cost-effective and environmentally responsible operations.

Approval of rate changes related to IT and OT modernization for regulated utilities depends on various factors, including the impact on utility operations and customer service, and the regulatory environment in which the utility operates. Regulatory bodies are more supportive of rate changes necessary to support modernization efforts when utilities can provide data demonstrating the benefits to customers and increased efficiency and reliability of the utility's operations. For example, if a utility can demonstrate that an IT and OT modernization effort will lead to reduced operating costs, improved reliability, or better customer service, regulators may be more likely to approve a rate change to fund the modernization effort. However, in some territories, regulatory bodies may have strict rules and guidelines regarding rate changes, which can limit the amount of funding that can be allocated to IT and OT modernization efforts. In other cases, regulators may be more flexible in their approach to rate changes and may be more supportive of innovative approaches to funding IT modernization.

COS regulation introduces several challenges for grid modernization:

- Regulators require that any proposed rate changes are reasonable and justified and in turn require the utility to provide detailed cost-benefit analyses and other evidence to support the proposed increases. There is uncertainty about the benefits and costs of grid modernization investments and whether they provide net benefits to customers. There are limited data regarding the costs, and especially the benefits to ratepayers of grid modernization implementation; thus, there is a higher bar to convince regulators of the value of grid modernization investment proposals.
- IT and OT modernization investments can have multiple and interactive effects. These can be difficult to analyze or justify separately, and benefits can be hard to quantify or monetize. Equity concerns may arise when some investments provide different benefits among different types of customers.

[7] "Performance-Based Regulation in a High Distributed Energy Resources Future: Future Electric Utility Regulation Report No. 3". January 2016. https://eta-publications.lbl.gov/sites/default/files/lbnl-1004130.pdf, p.viii

- Because IT and OT modernization costs may be capital expenditures that are typically recovered over a longer period, there can be delays in the utility's ability to recover costs which can impact the utility's financial performance.
- Alternately, some utility ratemaking rules may treat IT and OT modernization costs as O&M expenses that do not earn a rate of return, which disincentivizes utility pursuit of these upgrades and decreases utility awareness of potential modernization opportunities.
- Some electric utilities may not have the incentive to invest in new infrastructure or technologies because the regulatory framework limits their profitability or does not provide clear upside potential, and little incentive to innovate.[8]
- There is a lack of uniformity regarding the terms and benefits of grid modernization investments. Rate case filings often focus on features (switches, smart meters, etc.) rather than benefits or outcomes reduce operational costs, improve reliability, etc.) of what the utility is proposing.
- IT and OT modernization may be perceived as an incremental expense that is less urgent than other costs and hence may receive increased scrutiny. These other costs include replacement of aging assets, increasing system resilience to climate-driven extreme events, meeting growing demand due to electrification of buildings and transportation, and maintaining reliability.

Although many utilities have made some investments in the advanced distribution system technologies, traditional COS regulation may not adequately value the services provided by IT and OT and their role in effecting necessary system transformation.

V. Recommendations and Opportunities to Meet IT/OT Modernization

Standards and Certification Focused on Grid Modernization

Third-party testing and certification regimes are crucial for ensuring that devices and systems operate as intended. For grid modernization efforts, obtaining certification of IT and OT compatibility to a standard is essential to realize functional value from utility investments. However, publicly available databases indicate that only a few communications standards have associated testing and certification programs. This is complicated by the fact that, according to a 2019 National Institute of Standards and Technology (NIST) study, there are on the order of 150 IT and OT communication standards that are relevant to modern grid operations.[9] The disparity between the large number of available communication standards and small number of

[8] Kihm, Steve, Beecher, Janice and Lehr, Ronald. "Regulatory Incentives and Disincentives for Utility Investments in Grid Modernization." LBNL Publications. May 27, 2017. https://eta-publications.lbl.gov/sites/default/files/feur_8 _ utility_ incentives_for_grid_mod_rev_062617.pdf, p. 27-30

[9] Song, E., Nguyen, C. & Gopstein, A. "Review of Smart Grid Standards for Testing and Certification Landscape Analysis". NIST Technical Note 2042. April 2019. https://doi.org/10.6028/NIST.TN.2042

associated third party certification programs makes it difficult for asset-owners and system-operators to ensure communications between IT and OT devices and systems will be possible.

The issue of overlapping communications standards identified in the 2019 NIST study adds complexity to modernizing IT and OT operations that is compounded by the limited capability to ensure communications across standards through available testing and certification programs. Due to the abundance of available standards and the lack of available certification for communications, interoperability across systems possess a major challenge for grid modernization and frequently leads to organizations pre-determining their IT and OT communication strategies based on legacy standards rather than a thorough evaluation of their needs for grid modernization, via use-cases and/or functional requirements.

Organizations involved in grid modernization efforts should prioritize technical assessments to determine the most appropriate communication standards for their system or application. By doing so, the adoption of communication standards that enable interoperability and enhance the grid's capabilities can be accelerated, ultimately supporting the goals of modernization efforts.

One solution to this problem is to develop interoperable communications standards for IT and OT systems in the power sector. This can be achieved through collaboration among standards development organizations, industry stakeholders, Tribal Nations, and regulatory bodies. The development of more interoperable communications standards would simplify the testing and certification process for IT and OT systems, reducing the technical complexity and the need for bespoke test harnesses. This, in turn, would facilitate the implementation of grid modernization efforts by enabling devices and systems to communicate and operate as intended, regardless of the specific standard used.

Another approach to addressing the complexity of standards and certification would be to develop industry-wide guidance and use cases that describe best practices for applying existing standards and certification strategies to different aspects of grid IT and OT systems and clarifying the technical strategies for exchanging information between systems relying on different standards. These interoperability strategies and requirements could be incorporated into utility procurement language and regulatory approval strategies.

Comprehensive Electricity Planning Requirements

Grid modernization relies heavily on the policies and regulatory frameworks established by state legislatures and utility commissions; their decisions can either encourage or deter investment in innovative technologies including IT and OT investments. State legislatures have various options to promote adopting and deploying new technologies, including energy storage and demand response. By working alongside PUCs, legislatures can adjust the regulatory framework to better align customer and utility goals.

State legislatures hold significant power in shaping policy through statutory and regulatory requirements. PUCs, in turn, base their regulations on the underlying statutes set by the legislature. These regulations are crucial in directing investments and promoting innovation in the electric sector. PUCs can initiate studies to explore grid modernization, establish pilot programs, and require the use of planning programs such as integrated resource plans (IRPs) and integrated distribution system planning (IDSP).[10,11]

IRPs are comprehensive, long-term plans that utilities create to ensure a reliable and affordable supply of electricity to their customers. These plans include a range of resources, such as renewable energy, natural gas, and energy efficiency programs to meet future demand while minimizing costs and environmental impacts. Utilities are typically required to submit IRPs for approval by the state PUCs, which evaluates the plan based on a range of factors, including cost-effectiveness, reliability, and environmental impact. By ensuring that utilities are considering a range of resources and technologies, including those associated with IT and OT, and that their plans are cost-effective and environmentally responsible, regulators can help drive the adoption of renewable energy, energy efficiency, and other innovative technologies at the lowest cost to ratepayers.

IDSP is a comprehensive approach to planning and operating the distribution system that considers the integration of DERs, such as solar panels, wind turbines, and energy storage systems. IDSP involves the coordination of multiple stakeholders, including utilities, regulators, and customers to ensure that the distribution system can accommodate DERs while maintaining system reliability and cost-effectiveness.

IRPs and IDSP include key steps such as data collection and analysis, system optimization, investment planning, and implementation. These steps include identifying the need for IT and OT modernization and deploying the necessary infrastructure to accommodate DERs.

Alternative Ratemaking Policies

Policymakers and regulators have explored several alternative regulatory models as potential alternatives to the traditional cost-of-service approaches. Some of the most promising models include performance-based regulation (PBR), revenue decoupling, and incentive and value-based regulation.

PBR is a set of options that may be adopted to achieve a set of regulatory objectives. Under a **performance-based regulatory model**, utilities are rewarded for achieving certain goals or

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[10] Andersen, G., Cleveland, M. & Shea, D. "Modernizing the Electric Grid: State Role and Policy Options". NCSL. September 22, 2021. https://www.ncsl.org/energy/modernizing-the-electric-grid

[11] Nethercutt, Elliot. "Demand Flexibility within a Performance Based Regulatory Framework." National Association of Regulatory Utility Commissioners. January 28, 2023. https://pubs.naruc.org/pub/2A466862-1866-DAAC-99FB-E054E1C9AB13

outcomes, such as reducing costs, improving service quality, or increasing the adoption of renewable energy. This can provide strong incentives for utilities to innovate and find new ways of delivering services to their customers, while also holding them accountable for meeting specific performance targets. A PBR model consists of revenue adjustment mechanisms and performance mechanism.[12]

Revenue adjustment mechanisms include multi-year rate plans, earnings sharing, and revenue decoupling. **Multi-year rate plans** (s) are ideal for implementing innovation, new technologies and grid modernization efforts, as they allow more flexibility and time for executing higher efficiency strategies and reducing system costs. **Earnings sharing** allows the utility to keep a portion of the earnings it receives and require the rest of the earnings go to customers. With **revenue decoupling**, utilities are allowed to earn a fixed rate of return on their capital investments, but their revenue is decoupled from the amount of electricity they sell. This can incentivize utilities to encourage energy efficiency among their customers and invest in renewable energy projects and other initiatives that could reduce the need for new power plants.[13]

On the other side of the PBR model are performance mechanisms, which include performance incentive and shared savings mechanisms. **Performance incentive mechanisms** (PIMs) provide monetary rewards for achieving desired energy goals and serving customers' interests. They also allow utilities flexibility to meet traditional and emerging regulatory goals. A **shared savings mechanism** is an incentive in which the utility and customers share the net benefits from the energy investment.[14]

Value-based regulation seeks to align utility incentives with the broader social and environmental goals of the energy system, such as reducing greenhouse gas emissions or promoting equity and access. This can involve pricing and incentive mechanisms that encourage utilities to invest in renewable energy, energy storage, and other low-carbon technologies while ensuring that their services are affordable and accessible to all customers.

Overall, these alternative regulatory models offer a range of potential benefits over the traditional cost-of-service model, including stronger incentives for innovation, greater accountability for meeting performance targets, and better alignment with broader social and environmental goals. However, each model also has its own unique challenges and trade-offs, and policymakers and regulators will need to carefully evaluate the pros and cons of each model to determine which one is best suited for their objectives.

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[12] Andersen, Cleveland & Shea. "Modernizing the Electric Grid: State Role and Policy Options".

[13] Newton Lowry, M., Woolf, T. & Schwartz, L. "Performance-Based Regulation in a High Distributed Energy Resources Future: Future Electric Utility Regulation / Report No. 3". January 2016. https://eta-publications.lbl.gov/sites/default/files/lbnl-1004130.pdf, p.41-34

[14] Newton Lowry, Woolf, & Schwartz. "Performance-Based Regulation in a High Distributed Energy Resources Future". p.23

VI. Conclusion

The transition to a modern electric grid will require careful consideration of numerous solutions to increase reliability, affordability, efficiency, and resilience. Achieving IT and OT modernization requires policymakers and utilities to align customer needs with utility goals and provide a regulatory environment that encourages innovative technologies and market competition. State legislators play a critical role in shaping the legal framework for regulatory commissions and influencing the success of grid modernization efforts. To achieve equitable cost allocation, encourage competition, reduce costs, and promote cost-effective solutions, policymakers must adjust and create flexible policies that can adapt to a complex grid and changing market conditions. Coordination among stakeholders including Tribal Nations and the creation of a comprehensive grid modernization roadmap can guide policy and regulatory decisions toward achieving resiliency, competition, reliability, efficiency, and cost-effectiveness. Lawmakers have an opportunity to shape a modern energy system that benefits electricity consumers, businesses, industry, and society by setting guiding principles for grid modernization. Lastly, the Department of Energy (DOE) plays an important role in driving grid modernization using a range of Federal investments in energy infrastructure (see Appendix 2). Specifically, the IIJA allocates Federal investments to enhance the reliability and resilience of the grid as well as loan programs to finance large-scale energy infrastructure projects in the United States. Additionally, to transition to a modern grid, its necessary to address the current challenges associated with the siting and permitting for transmission infrastructure, which has been impeding the buildout of transmission infrastructure.

The Department also has an important role to play in simplifying the landscape of standards certification. One way to achieve this is by supporting stakeholder efforts in developing guidance documents and reference implementations that address common challenges faced by infrastructure owner/operators when upgrading from legacy standards. This could include best practices and other guidance on updating and integrating legacy equipment and IT and OT systems with the current state of the art. Clear and comprehensive guidance, standards, and regulatory requirements can help policymakers, electric utility providers, and customers to make informed decisions, reduce confusion, and promote interoperability. This will contribute to a more reliable, efficient, and resilient grid that better meets the needs of customers and society.

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Appendix 1: Modernization Rate Cases Case Studies

This section presents several cases studies on utilities filing for rate cases for modernization investments in recent years. This includes cases where rate recovery for grid modernization was denied, and recovery was allowed either through traditional ratemaking or alternative forms of regulation.

Ameren Illinois Company

In 2018, Ameren Illinois Company d/b/a Ameren Illinois (AIC) received regulatory approval of its proposed tariff for rebate programs for distributed generation projects that incorporated smart inverters. By the end of 2021, AIC replaced analog meters with smart meters for 1.2 million customers. Under the program, implementing smart meters allowed customers to access their energy usage data and access programs thereby reducing their energy usage and energy costs. This technology also provides quicker outage notifications, speeding up power restoration.[15]

Kentucky Power

Kentucky Power (KP) received approval from the Kentucky Public Service Commission (PSC) in 2021 to increase its revenues. The proposal also included a request to install advanced metering infrastructure (AMI), a grid modernization rider, an electric vehicle charging provision, and changes to the company's net metering tariff. Kentucky Power proposed an increase in its revenues of $70.1 million. The PSC reduced the base rate increase by $17.7 million to a final rate increase of $52.4 million. The order revised Kentucky Power's tariff on Off System Sales (OSS) to reflect that all OSS margins will be apportioned to ratepayers. Additionally, the order reduced specific nonrecurring charges by removing labor costs incurred during business hours. Under the order, PSC denied several items proposed by Kentucky Power, including a Certificate of Public Convenience and Necessity (CPCN) for the AMI system and a related Grid Modernization Rider to recover the annual costs to install the AMI system. The estimated cost to implement the AMI system was $35 million. KP failed to provide data in its rate filing to support the cost estimates, and PSC would only approve the system with sufficient evidence of the costs of alternative proposals. Rejecting the Grid Modernization Rider reduced revenue requirements by over $1.6 million.

Legislation enacted in 2019 removed the one-to-one net metering bill credit and authorized utilities to propose a replacement value for a customer-generator's energy. The PSC did not reach a decision on Kentucky Power's proposed changes to the Net Metering tariff because the utility failed to provide sufficient evidence to support its proposal.[16]

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[15] Final Order for 18-0191. Illinois Commerce Commission. August 15, 2018. https://www.icc.illinois.gov/docket/P2018-0191/documents/275527

[16] "CASE NO. 2020-00174." PSC. January 13, 2021. https://psc.ky.gov/pscscf/2020%20Cases/2020-00174//20210113_PSC_ORDER.pdf

In Case number 2020-00174 brought by Kentucky Power in 2021, the PSC approved a compensation rate for energy exported from net metering customers under Kentucky Power's newly offered net metering tariff, NMS II. The PSC modified the utility's proposed export rate. Kentucky Power proposed a compensation rate based on an avoided cost methodology. Avoided costs are the incremental costs a utility would incur if the utility were to purchase, spend, or generate the same amount of service from another source if the net metered customer's service was not in place. The Commission's order established a compensation rate based on avoided costs and included in avoided cost reasonable estimates of avoided generation, distribution, and transmission capacity, energy, ancillary service costs, and avoided environmental costs. Residential net metering customers who take service under Tariff NMS II will be compensated for exported electricity at $0.09746 per kWh, compared to Kentucky Power's proposed rate of $0.03553 per kWh. The PSC denied Kentucky Power's proposal to implement two time-of-use netting periods and directed Kentucky Power to net the total electricity consumed and the total electricity exported over the monthly billing period.

The PSC's order established several principles for net-metering and rate design, including evaluating qualified generating facilities as a utility system or supply-side resource; treating benefits and costs symmetrically to avoid bias; conducting long-term and incremental analysis; creating transparent and consistent methodologies. Kentucky Power's net metering tariff set up the framework to integrate more DERS in the future in ways that will benefit customers, utilities, and local communities.[17]

Southern California Edison

In 2015, Southern California Edison (SCE) filed its general rate case with the California Public Utilities Commission (CPUC). SCE requested approval of a 14.7 billion revenue increase, including $2.1 billion gird modernization investment. The CPUC denied most of the grid modernization requests because SCE did not demonstrate net benefits for customers. Additionally, the grid modernization plan did not account for other opportunities to use DER and other third-party services to reduce costs. However, the commission did approve investments in increased reliability and automation as well as a system management platform and central communications platform. [18]

In its next rate case in 2021, The CPUC approved a 7.63 percent increase for SCE's revenue requirement. The order authorized a revenue requirement of $6.89 billion for operations and capital investment. This resulted in a rate increase of 8.9 percent (or $12.41) for the average

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[17] "Case NO. 2020-00174." Psc. May 14, 2021. https://psc.ky.gov/pscscf/2020%20Cases/2020-00174//20210514_PSC_ORDER.pdf

[18] "Decision on Test Year 2015 General Rate Case for Southern California Edison." California Public Utilities Commission. November 15, 2015. https://www.documentcloud.org/documents/3688632-Decision-on-Test-Year-2015-General-Rate-Case-for

household. The order also approved several grid modernization measures, including distribution and transmission grids, substations, and energy storage investments.[19]

Hawaii

The constraints associated with the cost-of-service model have forced utilities to look for alternative methods to recover their investment from modernizing the grid. The following case provides an example of innovative state regulation that can be replicated and modified to facilitate integration of distributed energy resources (DERs) in other states. In Hawaii, regulators shifted away from the traditional cost-of-service model to alternative regulation for utilities. The alternative programs implemented in Hawaii provide more flexibility for utilities and encourage utilities to innovate and modernize the electric grid.

In 2015 the Hawaii Legislature established a renewable portfolio standard to produce 100 percent of electricity from renewable energy by 2045. By 2020, the state was producing 30 percent of its electricity from renewable energy and on the right trajectory to meeting its goal by 2045. In December 2019, the Hawaii Public Utilities Commission (HPUC) approved an order allowing Hawaiian Electric to transition away from the cost-of-service model towards Performance-Based Regulation (PBR. PBR includes a multi-year rate plan, which reduces the burden on the utility by lengthening rate case intervals from three to five years. The PBR was developed over three phases. The first phase established the PBR and prioritized renewable energy, lower costs, and customer service. Additionally, Hawaiian Electric could earn additional revenue if it achieved performance targets such as accelerating renewable energy integration. The second phase established a pilot process to support the development of new projects and service options. Additionally, this phase included annual revenue adjustment policies, consisting of revenue decoupling and earnings sharing mechanism, which protect Hawaiian Electric and customers from excessive earnings or losses. The third phase included an interconnection approval Performance Incentive Mechanism (PIM) to encourage faster interconnection timelines for small-scale solar and storage projects. Additionally, the phase created a low-moderate income energy efficiency PIM to incentivize collaboration between the utility and energy efficiency program administrator to provide low-to-moderate income customers with options to manage their energy usage.[20]

[19] "CPUC Issues Decision in SCE's 2021 Rate Case." California Public Utilities Commission. August 19, 2021. https://www.cpuc.ca.gov/news-and-updates/all-news/cpuc-issues-decision-in-sce-2021-rate-case

[20] (2022, April 1). Public Utilities Commission | Performance Based Regulation (PBR). Puc. https://puc.hawaii.gov/energy/pbr/

Appendix 2: U.S. DOE Grid Modernization Programs

Several DOE offices oversee activities designed to accommodate and support grid modernization and accelerate the advancement of digitization. These programs range from research, development, and demonstration (RD&D); grants, loans, and other financial assistance programs; and policy and planning initiatives. The relevant DOE offices and their focus areas include:

The **Advanced Research Projects Agency-Energy (ARPA-E)** advances high-potential, high-impact energy technologies that are too early for private-sector investment. ARPA-E focuses on transformational energy projects that can be meaningfully advanced with a small amount of funding over a defined period. Its projects include components and technologies needed to enable the future grid.

The mission of the **Office of Energy Efficiency and Renewable Energy (EERE)** is to accelerate the research, development, demonstration, and deployment of technologies and solutions to equitably transition America to a clean energy economy that benefits all Americans, creating good paying jobs for the American people—especially workers and communities impacted by the energy transition and those historically underserved by the energy system and overburdened by pollution. EERE's research, development, demonstration, and deployment (RDD&D) activities are organized among the following three pillars: energy efficiency, renewable energy, and sustainable transportation—all important elements of the modernized grid. EERE coordinates closely with the Office of Cybersecurity, Energy Security and Emergency Response (CESER) on DERs and recently released a new report called Cybersecurity Considerations for Distributed Energy Resources on the U.S. Electric Grid (October 2022), which outlines recommendations for building DERs systems that are cybersecure by design to better serve customers as America’s clean energy grid evolves.

The **Grid Deployment Office (GDO)** oversees activities that enhance the resilience of the grid in support of electric grid operators, electricity generators, transmission owners and operators, distribution providers and others. One of GDO’s divisions, the Grid Modernization Division, is administering the $10.5 billion-dollar Grid Resilience and Innovation Partnerships (GRIP) Program, as well as the $2.3 billion Grid Resilience State and Tribal Formula Grant program. The Puerto Rico Grid Recovery and Modernization Program have provided Puerto Rico energy system stakeholders with tools, training, and modeling support to enable the planning and operation of the electric system with greater resilience against further disruptions.

The mission of the **Office of Indian Energy Policy and Programs (IE)** is to maximize the development and deployment of energy solutions for the benefit of American Indians and Alaska Natives. The Office works within DOE, across government agencies, and with Indian Tribes and organizations to promote Indian energy policies and initiatives. IE works to provide direct, foster, coordinate, and implement energy planning, education, management, development, and efficiency. In addition, IE delivers programs that promote the Indian Tribal energy development, efficiency, and use; reduce or stabilize Indian Tribal energy costs; strengthen Tribal energy infrastructure, and electrify Indian land, housing, and businesses.

The **Loan Programs Office (LPO)** supports the deployment of technologies that will enable the energy transition. LPO's financial programs serve as a bridge to bankability for innovative and high-impact energy technologies, providing them with access to needed loans and loan guarantees when private lenders cannot or will not until a given technology has reached full market acceptance.

The focus of the **Office of Clean Energy Demonstrations (OCED**) is to deliver clean energy demonstration projects at scale in partnership with the private sector to accelerate deployment, market adoption, and the equitable transition to a decarbonized energy system. Its portfolio includes long duration energy storage, regional clean hydrogen hubs, and regional direct air capture hugs, to name only a few of the largest initiatives. In addition, it focuses on resilient energy solutions. The IIJA funded the Energy Improvements in Rural or Remote Areas (ERA) program, which seeks to improve the resilience, reliability, and affordability of energy systems in small communities across the country by leveraging DOE's expertise and experience in resilient energy solutions to modernize electric generation facilities, address disproportionately high electricity costs, and support new economic opportunities in rural and remote communities.

The **Office of Electricity (OE)** leads the Department's efforts to ensure that the Nation's electricity delivery system is secure and resilient to disruptions. OE has three divisions. The Grid Systems and Components Division leads national efforts to develop "next generation" technologies, tools, and techniques for the electricity delivery system through RD&D programs aimed at hardware components (and associated software) and integrated grid systems. The Grid Controls and Communications Division manages RD&D focused on secure communications, controls, and protection systems, including end-to-end systems for communications, grid modeling, measurement and controls, and operations and planning. The Energy Storage Division supports applied materials research in support of long duration storage. OE has also supported efforts to support states in the evolution of grid modernization. The Modern Distribution Grid (DSPX) has worked in close collaboration with California, New York, District of Columbia, Hawaii, and Minnesota utility regulatory commissions to develop guidance to assist in the development and evaluation of distribution grid modernization – described as a next-generation distribution system platform.

The **Office of CESER** is committed to enhancing the grid's security and resilience today and planning for the grid of tomorrow. As DERs, electric vehicles, and smart home appliances become more ubiquitous across the country, CESER works to ensure that cybersecurity is as fundamental as reliability and safety are in the electric sector today. CESER is also supporting state efforts to modernize the grid securely and resiliently. CESER is working with the Office of State and Community Energy Programs (SCEP) in developing State Energy Security Plans (SESP).

The **Office of SCEP** works with state and local organizations to significantly accelerate the deployment of clean energy technologies while catalyzing local economic development and creating jobs, reducing energy costs, and avoiding pollution. SCEP's foundational programs include the Weatherization Assistance Program (WAP) and State Energy Program (SEP), which have more than 40 years of successfully delivering energy savings across the country. In addition, working with CESER, SCEP has implemented the State Energy Security Plans (SESP) program required by IIJA. This requires states to assess the current energy security circumstances of the state and propose methods to strengthen energy security abilities of the state including enhancing reliability and end use resilience.