Member Report

DER Interconnection Guide

Published November 2020

Prepared for:

National Electrical Manufacturers Association

Section 1
Executive Summary

1.1 Introduction

The energy transformation is being propelled by growing customer demand for cleaner, more flexible, and cheaper solutions. This evolution will go well beyond the power grid and the power industry—it will affect the way we live, work, and move in our communities, as well as the way we use materials, produce and move goods, and provide services.

Distributed energy resources (DER) are an integral part of this transformation. They provide an economic and resilient solution to energy consumers at the grid edge. To cope with the increasing number of DER assets deployed and to ensure these are treated as equal within the power system, utilities, regional transmission organizations (RTOs), independent system operators (ISOs), and the federal government are implementing grid interconnection guidelines that DER installations need to follow. This report highlights the type and main characteristics of the regulations being implemented.

To cope with the increasing number of DER assets deployed and to ensure these are treated as equal within the power system, utilities, RTOs, ISOs, and the federal government are implementing grid interconnection guidelines that DER installations need to follow.

Electrical equipment manufacturers also need an overview of the process that DER installations need to follow to get interconnected. This report discusses how NEMA members' product can help installers simplify their interconnection processes by getting equipment certifications and following the required standards.

Finally, the report goes beyond DER interconnection requirements and shows how DER and equipment manufacturers can play an extended role in the future power system. Use cases showcase how equipment manufacturers and utilities can partner to create the right structure to capture all the value that DER can provide to customers, the grid, and ultimately, manufacturers.

Section 2
The Energy Transition

2.1 Past Energy System Design and the Energy Transformation

The energy sector is amid a major global transformation. During the next 5-15 years, a massive disruption across the entire energy value chain affecting a broad set of stakeholders will occur. This transformation is primarily being fueled by multilateral efforts focused on decarbonizing the global economy to address climate change and a shift toward a clean, intelligent, mobile, and distributed energy ecosystem. Within the energy transformation, external and internal pressures combine to create opportunities for new business models:

- A disruptive decoupling of linear value chains in the power industry as the grid moves away from a centralized generation model to a more distributed, networked, and dynamic system.
- An increasingly grid edge and customer-centric orientation in which two-way value flows—energy, financial, and data—facilitate a more diverse and complex ecosystem of stakeholders.

2.2 What Are Distributed Energy Resources?

Although the concepts and technologies behind distributed energy resources (DER) have been developing since the energy crisis in the 1970s, they have each been developing at an independent pace and without much interaction. In just the past few years, technological, economic, and regulatory changes have made the idea of integrated DER feasible for commercial and industrial (C&I) customers.

DER include distributed generation, energy storage, electric vehicle (EV) charging, and demand response (DR)[1]. DR includes smart HVAC systems, connected storage heaters, and internet-enabled traditional residential and commercial appliances like fridges. The control systems to optimize these technologies and the aggregation platforms to connect them create the link between DER assets and the grid. In this report, DER includes the following:

- Solar PV
- Natural gas and diesel gensets
- Other distributed generation
- Energy storage

[1] For the purpose of this report, energy efficiency is not considered DER because it results in a fixed and permanent reduction in demand.

- DR
- EV charging equipment

2.3 Why DER?

While energy consumers will continue to use electricity from the grid, DER technologies bring unique characteristics that make them an attractive proposition. DER are the only energy resources that can improve resilience and sustainability at the point of energy consumption.

2.3.1 Resilience

DER are becoming a cornerstone of power resiliency strategies both for energy consumers and grid operators. Consumers are increasingly deploying microgrids that include two or more DER technologies, like solar PV and storage, with smart energy management and control systems to enable DER to continue operating in island mode when a power outage occurs.

At the utility level, DER are integrated into a DER management system platform, working alongside an advanced distribution system management system to actively manage the distribution grid to reduce outages and their impact on the grid. DER on the grid could also be used to island sections of the grid (similar to microgrids) to reduce the geographical impact of a planned or unplanned outage or maintenance operation. DER can be used in a blackstart as well.

2.3.2 Sustainability

The introduction of low carbon intermittent electricity generation onto the grid is increasing the complexity of an electricity system designed to work around a few centralized, dispatchable generation units and one-way electricity flows. Compared to traditional energy system operations, the diversity and sheer number of DER assets that will be present in the future grid pose a significant operational challenge.

Integration and optimization of some DER can help utilities reduce greenhouse gas (GHG) emissions or meet other climate-related targets. Optimized battery storage can be used to store excess solar generation by day or wind generation by night to dispatch it either locally or into the broader grid during periods of peak demand. Connected thermostats and water heaters that can continuously cycle to reduce electricity demand without disrupting customer comfort will serve as valuable resources in decarbonization efforts. These efforts help reduce the time that more polluting plants are operating and can enable a cleaner energy mix.

Section 3

DER Drivers, Barriers, and Forecast

3.1 Drivers Promoting DER Growth

According to Guidehouse Insights, 160 GW of DER was installed globally in 2019,[2] or about one-third of all the power generation installed. Initially, DER deployments were supported by regulatory incentives, but other factors have surged in importance. These factors are examined in the following sections.

3.1.1 DER Economics Improvement

The costs of solar and storage, the backbone of integrated DER installations, have been falling continually at a fast rate for the last decade. Specifically, battery storage and solar PV costs have fallen by around 60%[3] and 80%,[4] respectively, in the last decade.

The costs of solar and storage, the backbone of integrated DER installations, have been falling continually at a fast rate for the last decade.

While much attention is paid to falling costs and the increasing efficiency of technologies, integrating DER also improves DER economics. Third-party aggregators or utilities use DER to produce a sufficient collective capacity to provide grid services and defer grid and capacity upgrade costs. Furthermore, coordination and co-optimization of multiple DER improves the overall value. A solar PV system and HVAC system have to coordinate to maintain occupant comfort at the lowest marginal cost; in this case, the HVAC would cool to the minimum temperature allowed in the set comfort levels when the sun is shining.

3.1.2 High Electricity Prices

DER deployments rely on the arbitrage (difference) between the levelized cost of energy of the DER system and the retail prices that customers must pay for electricity, including any demand charges. Retail prices vary significantly between jurisdiction, type of consumer, and time of consumption.

---

[2] Guidehouse Insights, *DER Global Database*, 1Q 2020, https://guidehouseinsights.com/subscription-services/der-database.

[3] National Renewable Energy Laboratory, *Cost Projections for Utility-Scale Battery Storage*, June 2019, https://www.nrel.gov/docs/fy19osti/73222.pdf.

[4] National Renewable Energy Laboratory, *Q4 2019/Q1 2020 Solar Industry Update*, May 28, 2020, https://www.nrel.gov/docs/fy20osti/77010.pdf.

3.1.3 Transport and Heat Electrification

Another trend supporting DER integration is the electrification of transport and heating. Like the power sector, heat and transport are also opting for technologies that help them decarbonize, such as EVs for transport and heat pumps for heating (at least at residential and commercial temperature operational ranges). This transition will increase demand for electricity. To cope with new power demand without significantly expanding poles and wires, these DER assets need to be managed to avoid compounding demand peaks. Instead, they need to shift their demand to times when the grid has spare capacity.

3.1.4 Capital Cost Deferral for Utilities

Distribution network operators have historically been more focused on asset managing and planning than managing network stability. Because these assets have been relatively predictable and low value, there has never been an economic case to improve real-time visibility into distribution network health. However, the growth of DER is increasing volatility in distribution networks.

Until recently, if a distribution grid utility needed to address an issue with congestion, a rate base-funded asset upgrade would typically follow. The tide is shifting against this asset-focused approach and toward market solutions.

In the past, providing the necessary flexibility at the grid edge was deemed too costly and was focused on large loads. The digitization of homes and businesses along with the proliferation of DER is changing that. Grid operators are under pressure from regulators to find innovative ways to accommodate growing electricity demand and intermittency without having to build larger networks.

The introduction of non-wires alternative (NWAs) concepts is relatively new in grid planning and operations. They are a new tool to integrate renewables, and especially DER, onto the grid.

The definition of an NWA varies across the US and globally. An inclusive definition would be the deployment of new technologies and programs to combine a variety of assets located at the grid edge that can be managed to defer or replace the need for more traditional wires-based solutions.

When managed intelligently, DER can help improve grid constraints—typically at the distribution level—that would otherwise require a capital investment; these investments include transformer upgrades and additional substations or distribution lines.

3.2 Barriers to DER Implementation and Penetration

Despite the growth observed in DER installations, technical and regulatory barriers are still slowing down deployments.

3.2.1 Complex Regulatory Environment

Regulations push for more DER adoption, but they are conscious of the issues DER can pose. Barriers include uncertainty in integrated DER performance, causing reluctance in permitting, and regulatory rules that hamper expansion efforts.

Transmission and distribution (T&D) system operators at the wholesale and retail levels are often reluctant, or uncertain, of how to permit DER participation in the full range of electricity market products (capacity, ancillary services, etc.). These feelings are because they are wary of these flexible assets and their perceived lack of reliability and visibility.

In addition, evaluation, measurement, and verification methods may fail to capture the full value of DER integration. There can be uncertainty of how to best determine DER asset performance following a grid event or the locational value of DER. While well-established methods for evaluation exist (e.g., the California Independent System Operator 10-10-10 rule for determining the counterfactual electricity consumption for a DR event), these methods may not fully capture the true value.

3.2.2 Fragmented Technology and Installer Ecosystem

Customers, especially residential and small and medium businesses, tend to spend limited time thinking about energy and are typically unfamiliar with the technologies and tariffs they can use to better manage electricity costs. This unfamiliarity is amplified by the often unclear nature and value of connected DER via time-of-use optimization, non-energy benefits, grid services, DR participation, and co-optimization of DER.

3.2.3 Lack of Public Awareness

Customers have to be convinced it is in their favor to deploy DER and participate in utility or aggregator DER programs. Given the bigger returns from individual customers, time can be invested in selling to C&I customers. The residential segment is harder. Residential customers are used to a certain way of purchasing electricity. In many states, solar systems are either more economic or at cost parity with grid-sourced electricity. Yet, only a small proportion of homes have installed solar systems to date. Apathy and lack of information play a huge part in this lack of traction. While the economic rewards from market participation could be the catalyst for rapid solar adoption, DER integration is by nature highly complex.

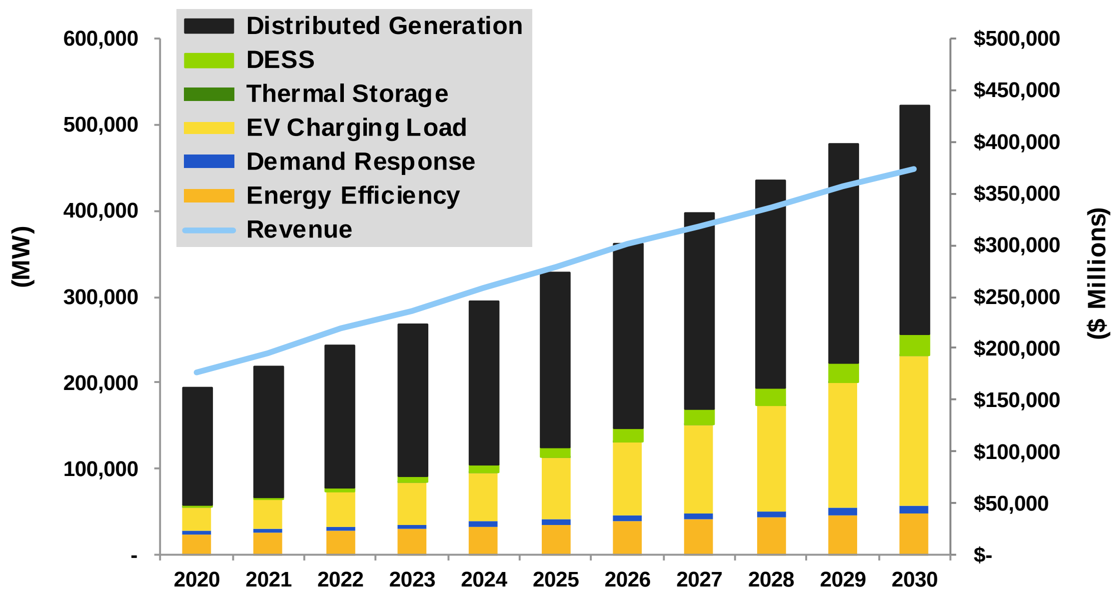
3.2.4 Limited Grid Infrastructure or Required Distribution Upgrades

Another barrier to DER deployment is the physical constraint that the current grid infrastructure has to accept new DER interconnections. The cost of installing DER might rise significantly if a feeder line, transformer, or substation needs to be upgraded before the assets can be connected or if the asset needs to be curtailed frequently. DER can also be part of the solution—for example, by using batteries or managed loads to ease grid constraints.

3.3 Expected Uptake of DER

According to Guidehouse Insights' *DER Database*,[5] the DER market reached nearly 160 GW of capacity in 2019. Annual installed capacity is expected to expand at least 3 times by 2030. New installed DER capacity is already outpacing new installed centralized capacity globally. This represents a significant tipping point in the energy transformation.

Chart 3-1. Annual Installed Total DER Power Capacity and Revenue by Technology, World Markets: 2020-2030



(Source: Guidehouse Insights)

[5] Guidehouse Insights, *DER Global Database*, 1Q 2020, https://guidehouseinsights.com/subscription-services/der-database.

Section 4

Regulatory and Statutory Considerations for Successful DER Integration

4.1 Federal Level

Most regulations regarding DER integration are set at the regional or state regulatory level. In the case of interconnection guidelines within utilities, the Federal government, through the Federal Energy Regulatory Commission (FERC) and the US Department of Energy (DOE), is becoming an important actor by advancing new rules for customer-side load and generation.

Most regulations regarding DER integration are set at the regional or state regulatory level.

4.1.1 FERC Order No. 2222

The FERC issued a breakthrough order on September 17, 2020. This order adopted rules aimed at removing barriers to the participation of DER in organized markets for electric energy, capacity, and ancillary services operated by regional transmission organizations (RTOs) and independent system operators (ISOs). Order No. 2222 builds on reforms previously undertaken by the FERC and, once fully implemented, should be a significant step toward opening up RTO/ISO markets to competition, facilitating the new entry of resources and fostering business model innovation.

In the order, the FERC put forward a vision in which swarms of small DER will be put into an aggregation such as a virtual power plant, allowing DER to provide a variety of products and services and compete with more conventional resources in RTO/ISO markets. The FERC is fairly open to individual DER and DER aggregations that can take advantage of the new rules. Order No. 2222 and the FERC's new regulations define DER broadly: "We define a distributed energy resource as any resource located on an electric utility's distribution system, a subsystem of the utility's distribution system or behind a customer meter." There is no minimum size for specific DER; still, aggregations should be at least 100 kW.

The FERC also avoided restricting DER aggregation locations, requiring RTOs/ISOs to fulfill locational requirements that are "as geographically broad as technically feasible." The FERC is interested in DER participation in wholesale markets. Such conditions should address transmission system features like congestion, and markets will enable aggregators to identify locations where DER can provide the most value when integrating into existing planning practices and avoid reliability issues.

4.1.2 DOE Support

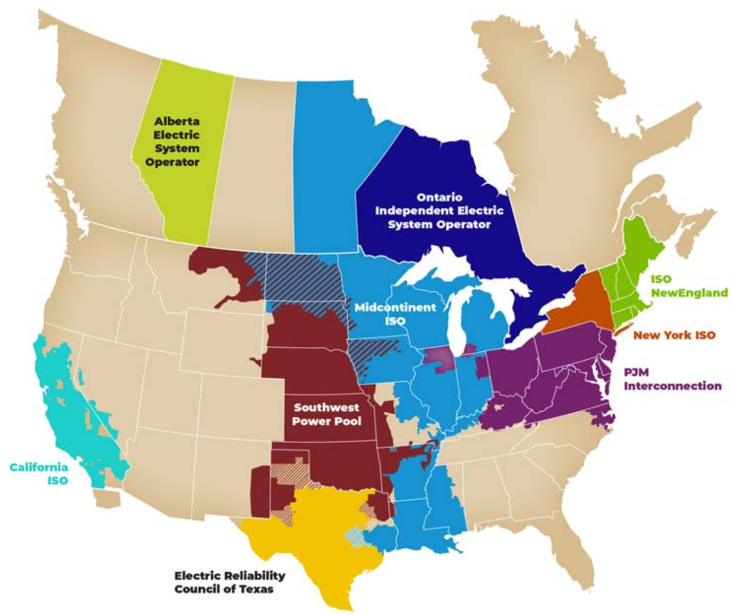
Despite not being a top priority of federal energy policy, the DOE continues to support renewable energy, efficiency programs, DR, and DER. In 2018, DOE allocated an estimated $860 million to support energy efficiency, renewable energy, and clean transportation research and development.

The Research and Innovation Act,[6] which became law in September 2018, specifically authorizes DOE to conduct basic research in chemistry and material sciences to advance solar fuel systems and electricity storage. This act also instructs DOE to use resources within the Office of Science and Office of Energy Efficiency and Renewable Energy and provides direction on how to conduct basic research.

4.2 Regional and State Level (ISO/RTO and Distribution Level)

North American ISOs and RTOs are all at varying stages of DER integration. As DER technologies proliferate across the continent, they can provide capacity and ancillary services to the regional markets. However, these technologies will require their own set of rules when compared to traditional fossil generation.

Figure 4-1. North American ISO/RTO Territories



(Source: ISO/RTO Council)

[6] Department of Energy Research and Innovation Act, Pub. L. No. 115-246, 132 Stat. 3130 (2018). https://www.congress.gov/bill/115th-congress/house-bill/589.

Despite the federal scope of FERC No. 2222 noted in Section 4.1.1, individual ISOs and RTOs experience the unique benefits and challenges of integrating DER into their respective wholesale markets due to regional geography and market structure.

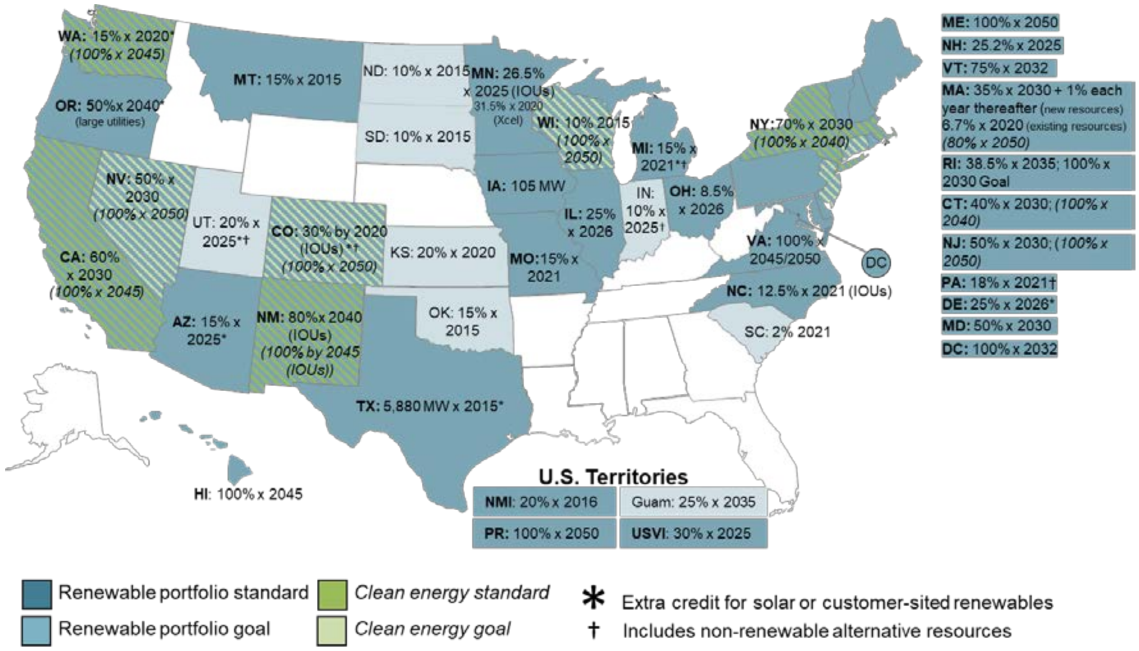
4.2.1 Renewable Energy Goals Status

State public policy has been a key driver of DER deployment in the US. DER targets are the most direct and visible instrument that officials have used to catalyze their in-state storage industries. The main regulatory tool used by states to promote renewables are renewable portfolio standards, which mandate specific levels of renewables utilization in their states. Currently, 29 states and the District of Columbia have a renewable portfolio standard, three states have a clean energy standard, eight states have renewable portfolio goals, and two states have clean energy goals.

DER targets are necessary complements to state clean energy policies such as clean energy standards and renewable portfolio standards. As non-solar DER, and especially energy storage, is a relatively new resource in many states, DER targets drive learning-by-doing among utilities, regulators, and agencies. States have incorporated various criteria into target design such as using megawatt-hours instead of megawatts in Massachusetts, creating carveouts by market segment in California, and introducing competitive procurement requirements in Virginia. In some states, the legislature has delegated authority to utility commissions to develop targets, while in other states the legislature has specified the target.

Regardless of approach, the indispensable element for making effective DER targets is follow-through, in which state regulators play an important role. For this reason, as of 2020, most laws establishing DER targets have assigned implementation and follow-through measures to state regulators. The sharing of power between legislative direction and regulatory implementation makes goals, targets, and mandates effective.

Figure 4-2. Renewable and Clean Energy Portfolio Standards Overview by State



(Source: DSIRE [Detailed Summary Maps](#), September 2020)

4.2.2 Building Regulation

DER need to comply with local building regulation because they are connected to the electric circuit installation and could become a personal safety and fire risk. Cities and counties in most states are required by state law to enforce building standards for DER. Cities and counties may adopt local laws to modify these state building standards under limited circumstances because of local climatic, geological or topographical conditions.

To reduce the environmental impact of new buildings, a new trend is appearing in building regulation codes. Regulators around the country are looking for ways to decarbonize energy consumption at home. One that might have the most impact in the short term is California's Self-Sufficiency Standard.[7] Other states like Massachusetts are following the California example.

4.2.3 Case Study: California

California is often viewed as a leader in decarbonization. The state was one of the first to set renewable energy targets and is actively modernizing its energy grid with distribution deferral opportunities.

---

[7] Pearce, D., Brooks, J., *The Self-Sufficiency Standard for California*, November 2000, http://selfsufficiencystandard.org/sites/default/files/selfsuff/docs/CA2000_methodology.pdf.

4.2.3.1 *100% Clean Energy Target*

Following Hawaii, California is the second state to set a goal for 100% clean, emission-free electricity by 2045. Senate Bill 100 was signed by former Governor Jerry Brown in 2018, and makes California, the world's fifth largest economy, committed to carbon neutrality. California also has interim renewable energy targets, spurring investment in distributed renewable generation. The state aims to be powered by 50% renewable electricity by 2025 and 60% by 2030.

While clean energy does not exclude nuclear generation, the California Public Utilities Commission (CPUC) has stringent waste disposal capabilities requirements that effectively block new nuclear generation development. As the state's single remaining nuclear plant, Diablo Canyon, will begin the process of decommissioning in 2024, the demand for other sources of renewable electricity generation will grow.

The City of Berkeley announced that it would ban natural gas infrastructure in new low rise residential buildings beginning January 1, 2020. Other California cities, including San Francisco, San Jose, Santa Rosa, and Petaluma, are following in Berkeley's lead and considering legislation that places bans or limitations on natural gas hookups in new construction.

4.2.3.2 *Distribution Deferral Opportunities*

In 2014, the CPUC announced its Distribution Resources and Integration of DER proceedings. With the goals of helping California reduce its GHG emissions and increasing the share of renewable generation, the Distribution Infrastructure Deferral Framework provides standards and criteria for the state's three investor-owned utilities to apply to distribution projects to identify where DER may replace traditional poles and wires upgrades. All three investor-owned utilities in the state are required to explore distribution deferral opportunities (DDOs) and the first cycle of annual reporting was implemented in 2018. DDOs are ranked relative to other opportunities discovered by the utility. However, given their relative nature, rankings do not ensure that a given DDO will be cost-effective; tier 1 or more highly ranked projects have a greater chance of going out for request for offers.[8]

Despite not explicitly being titled NWAs, project developers and analysts have largely equated DDOs to NWAs. The CPUC implementation of the Distribution Infrastructure Deferral Framework has created an annual process that encourages opportunities for DER to replace traditional grid upgrades and investments.

---

[8] California Public Service Commission. *California Smart Grid Annual Report to the Governor and the Legislature in Compliance with Public Utilities Code § 913.2.* 2018.

4.2.3.3 California ISO

The California ISO is updating its regulatory framework related to energy storage and other DER through its Energy Storage and DER (ESDER) initiative. The California ISO is also reviewing its capacity market's soft offer cap compensation calculations.

4.2.3.3.1 ESDER Initiative

The focus of the ESDER[9] initiative is on enhancing the ability of ISO-connected and distribution-connected resources, including rooftop solar, energy storage, plug-in EVs, and DR, to participate in the ISO market. Phase 1 and 2 have been implemented, Phase 3 began its implementation phase in fall 2019, and work on Phase 4 commenced in July 2019.

Phase 3 developed enhancements to the proxy demand resource participation model and a new load shift product:

- Introduced new bidding and real-time dispatch options
- Removed the single load-serving entity aggregation requirement and the settlement application for a default load adjustment
- Introduced the recognition of submetered EV supply equipment load curtailment as a separate contribution to resource performance
- Developed an energy storage load shift product

Two resource models introduced in 2012 provide opportunities for storage technologies to participate in the wholesale ancillary services market and energy market:

- **Pumped storage resources** act as load while using energy to pump water to higher elevation reservoirs and then act like generators by creating energy when releasing water back to lower reservoirs.
- **Nongenerator resources** can serve as both generation and load and can be dispatched to any operating level within their entire capacity range.

Phase 4 will see enhancements to the ways energy storage can be optimized by improving the nongenerator resources model and bidding requirements for storage participation.

[9] ESDER initiative status information can be found here: http://www.caiso.com/StakeholderProcesses/Energy-storage-and-distributed-energy-resources

4.2.3.3.2 Capacity Markets Soft Cap Review

In 2014, the California ISO introduced a soft offer cap[10] to ensure that as many participants as possible bid into the capacity market. The soft offer cap was set using forward fixed costs for a new, large gas-fired combined cycle resource (includes insurance, ad valorem, and fixed operations and maintenance costs but not capital, financing costs, or taxes).

Bids under the soft cap are not reviewed by the California ISO, but bids above the soft cap must be justified based on cost of service. A review process is triggered every 4 years. In August 2019, the California ISO issued the following recommendations:

- Retain the existing soft offer cap of $75.67/kW-year ($6.31/kW-month).
- Implement a three pivotal supplier test for annual designations and use cost of service compensation for designations made to resources that fail the test.
- Implement changes proposed in the Reliability Must-Run and Capacity Procurement Mechanism Enhancements initiative for bids above the soft offer cap. The initiative details the schedule of the assets and how compensation will be estimated to ensure it does not include market rents above the resource costs to operate in the market.

4.2.3.4 California's Energy Code

In a move to reduce energy use by more than 50%, the California Energy Commission (CEC) voted on May 9, 2018 to support a series of reforms designed to require new homes to comply with standards of self-sufficiency, including requiring solar.

The new requirement took effect on January 1, 2020, and focuses on four areas: residential and nonresidential ventilation requirements, nonresidential lighting requirements, updated thermal envelope standards, and smart residential PV systems. CEC aims to "promote installing solar photovoltaic systems in newly constructed residential buildings. The systems include smart inverters with optional battery storage."

The requirements go beyond solar; CEC also included other DER technologies in the mix because it also aims to "encourage battery storage and heat pump water heaters that shift the energy use of the house from peak periods to off-peak periods." The new requirements align well with previous time-of-use electricity

---

[10] California ISO. *Capacity Procurement Soft Offer Cap Straw Proposal*, July 24, 2019. https://www.caiso.com/Documents/StrawProposal-CapacityProcurementMechanismSoftOfferCap.pdf

pricing regulation in California, which was mandated starting in 2018 for solar installations.

4.2.4 Case Study: New York

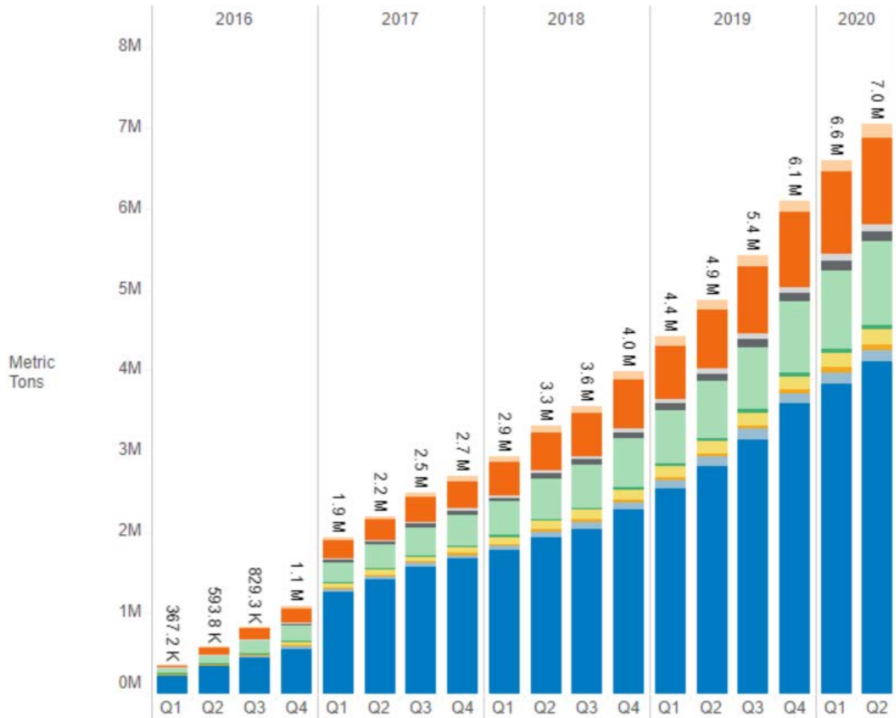
Between nuclear subsidies, the Reforming the Energy Vision campaign, and the development of the country's first non-pipes solution to relieve natural gas infrastructure constraint, New York has also made headlines for its 100% clean energy target and an accompanying statewide energy efficiency increase for the buildings sector.

4.2.4.1 100% Carbon-Free Target

New York has set a variety of targets around emissions and energy reductions, all of which contribute toward the statewide goal of achieving 100% carbon-free electricity by 2040 and a net-zero carbon economy by 2050. The state's Climate Leadership and Community Protection Act's[11] ambitions are the second most aggressive in the country as of fall 2019, following only Washington, DC's 100% renewable energy by 2032. New York is also the fourth most populous state in the US and has the third largest state economy, adding to the ambition of the climate targets.

[11] New York State, "Climate Act," accessed November 2020, https://climate.ny.gov/.

Figure 4-3. Gross Annual CO_2 Emissions Reductions by Administrator, New York: 2016-2Q 2019



(Source: New York Reforming the Energy Vision Clean Energy Dashboard)

Interim targets across New York include state utilities sourcing 70% of their energy from renewable sources by 2030, up from a previous target of 50%. Senate Bill 6599 also includes the mandated deployment of the following:

- 9 GW of offshore wind by 2035
- 6 GW of distributed solar by 2025
- 3 GW of energy storage by 2030

Progress toward the 2040 target will be formally examined in 2024, with subsequent biannual reviews scheduled.

4.2.4.2 Statewide Energy Efficiency Increase

New York is also accelerating energy efficiency in buildings through its BuildSmart NY initiative. An initiative in place since 2012, state buildings should achieve a 20% energy efficiency improvement by 2020. The New York Power Authority has financed $800 million in energy efficiency projects between 2012 and 2017, and the state is estimated to save an annual $49 million.[12]

While the requirement is restricted to state-owned buildings, municipalities are encouraged to comply or to set their own targets. New York City made headlines in spring 2019 following the announcement of its Climate Mobilization Act, which requires a building efficiency improvement of 40% by 2030 and 80% by 2050. Buildings with high emissions that cannot prove a reduction in emissions by 2024 face fines, as large buildings constitute 30% of New York City's GHG emissions.[13]

New York City is not the only municipality acting to reduce emissions and improve efficiency locally. Following the BuildSmart NY announcement, the New York Power Authority launched the Five Cities Energy Plans for Albany, Buffalo, Rochester, Syracuse, and Yonkers. Targets in these cities align with the 20% by 2020 goal set by the statewide initiative.

4.2.4.3 New York Independent System Operator

In 2017, the New York Independent System Operator (NYISO) launched a DER roadmap to design a new market model that enhances DER technologies' participation in the ISO's energy, ancillary services, and capacity markets. Much uncertainty remains over the number of DER assets that should be expected when planning and operating the grid. The New York State Public Service Commission has moved toward a Value of DER concept in which DER is compensated for the value they offer based on their location and performance capabilities. The Value of DER concept is still unfolding and, it remains to be seen to what extent DER will respond to the distribution-level price signals and how those signals interact with wholesale market signals.

NYISO continues to work with stakeholders and policymakers as it leads efforts to integrate DER into the grid.

4.2.4.3.1 Granular Pricing

To improve price transparency and facilitate DER investment and operation, NYISO and New York's distribution utilities have developed a methodology to offer more locational pricing points on the transmission system. Current prices are calculated and published on a zonal basis every 5 minutes. However, this approach does not provide DER the necessary level of granular pricing needed to determine the most effective locations within a zone to invest.

---

[12] ACEEE, "New York State Summary*," State and Local Policy Database,* last updated June 2018.

[13] Guidehouse Insights (formerly Navigant Research), "Demand-Side Management Programs to Support New York's Climate Mobilization Act*," Guidehouse Insights Blog,* April 30, 2019, https://www.navigantresearch.com/news-and-views/demandside-management-programs-to-support-new-yorks-climate-mobilization-act

To overcome this issue, NYISO will publish intrazonal prices, which offer more granular signals to precisely identify locations on the grid where DER will be most beneficial. NYISO will work with the distribution utilities to identify these pricing points. Using granular pricing in this manner will encourage investment at the most economically efficient transmission locations.

4.2.4.3.2 Storage Deployment Target

Governor Cuomo's 2018 State of the State address called for a $200 million investment from the New York Green Bank to support the development and deployment of up to 1,500 MW of energy storage capacity by 2025. The goal of the initiative is to drive down costs for energy storage while strategically deploying storage resources in locations where they best serve the needs of the grid. The New York State Energy Research and Development Authority will initially focus on storage pilots and activities that reduce barriers to deploying storage, including permitting, customer acquisition costs, interconnection, and financing costs.

NYISO filed a comprehensive set of rules with the FERC that will allow the expansion of wholesale market participation for energy storage. NYISO's Energy Storage Resource participation model will allow storage resources to either self-manage their energy levels or use NYISO's energy level monitoring capabilities.

4.2.4.3.3 Carbon Pricing

NYISO is in the process of introducing carbon pricing into its wholesale electricity market. In October 2019, Analysis Group research determined that carbon pricing can help the state meet its clean energy goals faster and more cost-effectively while reducing emissions and maintaining grid reliability. Adoption of a carbon price would help to send efficient price signals to wholesale market participants about the value of clean energy resources and would establish an electric system strongly aligned with the goals of the Greenhouse Reduction Act[14] launched by the Governor Cuomo in June 2019.

NYISO's proposal would incorporate a carbon price in the NYISO-administered wholesale energy markets in dollars per ton of CO_2 emissions resulting from power plant operations. The carbon price would be based on the social cost of carbon emissions and established by New York State officials.

Retail electricity suppliers would be charged the locational price for power they need for their consumers, with that price reflecting carbon-related costs. They would also receive a credit to substantially offset the effect of carbon pricing

[14] New York State Department of Environmental Conservation, "Reducing Greenhouse Gas Emissions – Limiting Future Impacts of Climate Change," accessed November 2020, https://www.dec.ny.gov/energy/99223.html.

because NYISO would return the carbon charges collected from generators that emit CO_2 to consumers.

The carbon charge would provide incentives to power suppliers with low or no carbon emissions, including for innovative low carbon technologies that may not yet be developed or be commercial in wholesale markets that do not provide compensation for the value those resources provide.

4.3 Individual Utility Considerations

4.3.1 DER Interconnection Practices

DER integration strategies vary from utility to utility depending on the local DER penetration, grid constraints, decarbonization strategies, and regulator push to support DER or new strategies of grid constraint management. DER integration practices cover a wide range of activities—from the interconnection of DER to the grid, to DER program planning and deployment, measurement and verification, and settlement.

DER integration strategies vary from utility to utility depending on the local DER penetration, grid constraints, decarbonization strategies, and regulator push to support DER or new strategies of grid constraint management.

4.3.2 Interconnection Guidelines

A utility's DER interconnection guidelines provide direction applicable to customers planning to interconnect and operate DER, including generators, in parallel with the distribution system. The guidelines are intended to provide standards that apply to the various aspects in which customers with electricity generating assets interface with the grid.

Individual utilities develop their own rules and processes to manage the interconnection of DER assets into their grid. DER interconnections are usually evaluated for the following:

- Safety of the general public or utility personnel
- Risk of degradation to services for customers due to interruptions or power quality events
- Compromise of security or reliability of electrical systems

Owners of approved DER interconnection participants are normally required to be responsive to the utility's direction and instructions during emergency conditions or to remove the DER from service when the utility is performing work on the circuit to which the DER is connected. DER interconnection requirements usually vary depending on the peak generation capacity of the DER. Requirements can also vary if using pre-certified equipment for low power systems (usually up to 25 kW); the requirements increase depending on the capacity and total system configuration, which is especially true if the equipment used has not been certified by a lab. In general, the interconnection process includes the steps outlined in Figure 4-4.

Figure 4-4. Typical DER Interconnection Process

(Source: Guidehouse)

An example DER interconnection guideline by San Diego Gas and Electric can be seen here.

The interconnection process for small systems (up to 25 kW to 50 kW) typically take between 30 days and 45 days. This increases to around 60 days for systems up to 5 MW in capacity.

The technical review is the most important aspect from an equipment manufacturer point of view. A technical review of each interconnection application is generally made to confirm the operation of the proposed DER system is consistent with the technical requirements of the power delivery system and does not adversely impact other customers.

4.3.2.1 Technical Review

The following are the most common requirements evaluated during the technical review process:

- **Protection requirements:** The protection requirements vary depending on specifics of the DER. Some of the protection schemes required include direct transfer trip, specific transformer configurations, transient overvoltage limits, specific short-circuit current ratings, a protective relay, and basic insulation level rating.
- **Stability studies:** Severe disturbances on the power system can cause a synchronous generator to lose synchronism with the power system. A large generator operating in this unstable manner can create large power and voltage fluctuations and can severely stress the generator and power system equipment and may affect other customers as well. Based on accepted industry protection guidelines, out-of-step protection is required to address stability concerns. Typically, a three-phase fault followed by a circuit breaker

failure will be studied to ensure that the interconnection design provides for an adequate stability margin.

- **Metering requirements:** Utilities set specific metering configurations that are acceptable. These requirements include the metering devices that comply with their metering standards, making them the only ones approved on their grid.
- **Telemetry requirements:** Telemetry requirements vary depending on utility, size, and type of the DER. Larger projects would need to have real-time SCADA to allow utilities to continuously monitor the DER performance, its performance during grid faults, voltage and frequency feeder loading, and islanding operations.
- **Access requirements:** Utilities might require right of access to interconnect and monitor DER assets.

4.3.3 Hosting Capacity

Another factor affecting individual utilities is their hosting capacity. Hosting capacity is defined as the amount of generation or demand, including DER, that can be connected to a distribution grid without adversely affecting the reliability or voltage quality[15] at any point in time for other customers without performing significant grid upgrades. Hosting capacity analyses usually consider voltage/power quality constraints, thermal constraints, protection limits, safety, and overall reliability to arrive at a capacity (kW, MW) of new generation or load that can be accommodated at a specific location on a distribution circuit.

Essential to the approach are the selection of performance indices, like metrics for overvoltage or overcurrent, for the grid and acceptability limits for those indices. The hosting capacity is the amount of new production or consumption where the first performance index reaches its limit. For example, the risk of overvoltage rises with small amounts of new generation connected to a part of the grid with only consumption while the risk of overcurrent will initially decrease.

Hosting capacity depends on location—it is unique to each specific distribution feeder. Given that customer needs are always changing, a hosting capacity analysis conducted today may yield different results than an analysis prepared 6 months or 1 year from now. In general, carefully crafted hosting capacity analysis can give DER developers insight into where on the grid DER can interconnect and potentially, on a forecast basis, where utility upgrades may be needed in anticipation of DER growth.

Historically, static rules have been used to provide a preliminary estimation of available capacity for interconnecting new DER. These include generation as a

[15] Bollen, M., Hassan, F. *Integration of Distributed Generation in the Power System*; Wiley-IEEE Press: Hoboken, New Jersey, USA, 2011.

percentage of peak load on a circuit or a percentage of minimum daily load. For example, since the late 1990s California's interconnection procedures for small generators (Rule 21[16]) has established a threshold for a supplemental interconnection review of 15% of peak demand. An alternative method is to limit at a percentage of minimum daytime load because the minimum load during the time when solar is producing is most relevant to whether the generation will cause challenges for the distribution system by producing energy flows back toward the substation.

New methods to assess hosting capacity are appearing where the characteristics of an individual line segment in a distribution system are assessed to ensure that DER do not result in violations of power quality/voltage, safety, protection, thermal or safety, and reliability limits. The result of the hosting capacity analysis provides a more transparent view of the potential risk that new DER could bring and suggests solutions to get the interconnection approved, like participating in DER programs to give the utility control of the assets in case it needs to curtail it.

4.3.4 DR and DER Programs

Managed DER programs are used by vertically integrated utilities. In these programs, utilities usually offer one or more DER technologies that customers can buy from them or that are supplied by a third party, sometimes at a subsidized price. In exchange, consumers have to agree to share data and often partial control of the installed device. Until now, this strategy has been used successfully to roll out residential smart thermostat DR programs, but there are pilots that include electric water heaters and heat pumps, batteries, EV chargers, and PV systems.

The following case studies highlight how partnerships between utilities and electrical equipment manufacturers are essential to maximize the value of DER for the customer, the utility, and ultimately, the manufacturer.

4.3.4.1 DER Integration Case Study: Green Mountain Power

Green Mountain Power (GMP) is building the utility of the future ecosystem for its customers through its vertically integrated franchise in Vermont. GMP created a marketplace where its customers can get different DER products through direct sales (upfront payment), rent, or thorough GMP's financing services. The products range from

> *By partnering with GMP, OEMs are offering their product at a price subsidized by the utility.*

[16] California Public Utilities Commission, "Rule 21 Interconnection," accessed November 2020, https://www.cpuc.ca.gov/rule21/.

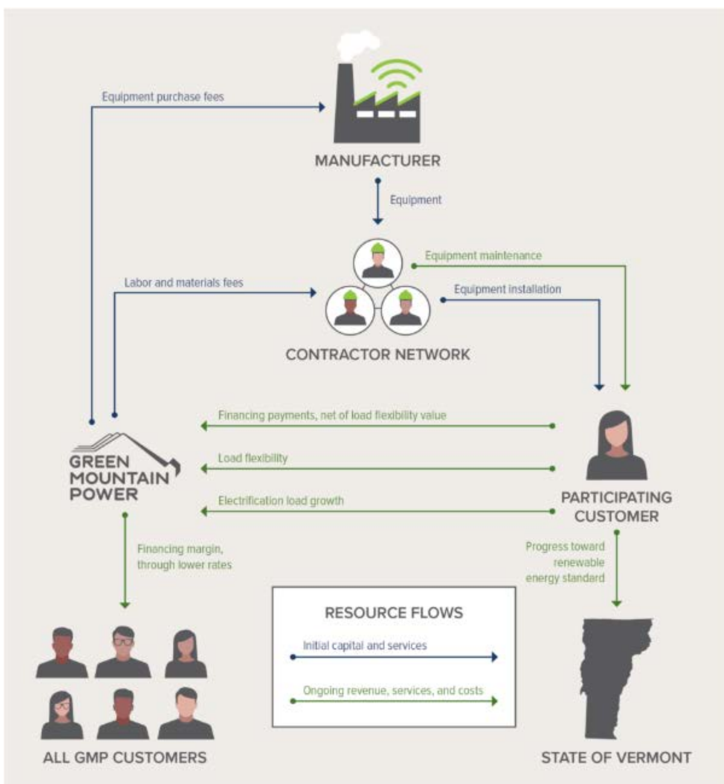
free control systems from Sensibo, Nest, Aquanta, or Mello to EVs from Nissan and GM.

GMP then enrolls customers with the right smart appliances in one of its rates designed to take advantage of the appliance smart capabilities to control the load or charging/discharging patterns to balance the grid.

One example of this is the utility's Tesla Rider Service. This service is available for customers who wish to install a Tesla Powerwall for reliability purposes while also allowing GMP to control such equipment. Reliability is improved by using the battery during power outages. Reduced rates are also available for customers who allow GMP to use the energy stored in the battery for peak reduction purposes. For customers that own a Tesla battery, GMP offers a monthly bill credit of $31.76 if they allow GMP to control the battery.

GMP's strategy allows it to tap into different revenue streams generated by DER—direct sales margins, financing, device servicing and, by keeping those assets within GMP control, cost reduction in grid reinforcements and new central generation capacity. By partnering with GMP, OEMs are offering their product at a price subsidized by the utility.

Figure 4-5. GMP DER Aggregation Solution



(Source: Rocky Mountain Institute)

4.3.4.2 *DER Integration Case Study: Arizona Public Service*

As of the end of 2Q 2020, Arizona followed only California in the number of solar PV installations in the state. Arizona Public Service (APS) integrated DER (iDER) programs incentivize customers in the residential and multifamily segments to adopt smart thermostats, efficient electric water heaters, solar panels, and battery storage to absorb excess solar generation on the system during the midday hours.

- **Cool Rewards** helps the utility manage peak demand while customers earn annual incentives for granting the utility access to their smart, connected thermostat. During periods of peak demand, the utility adjusts the thermostat setpoint by a couple of degrees to support grid reliability.
- **Reserve Rewards** program finances a grid-connected heat pump water heater in exchange for access to control the water heater and shift heating load to periods outside of peak demand. Customers on time-varying rates may benefit as their water heater draws electricity during low cost periods when solar generation is high.
- **Solar Communities** provides solar panels, owned and operated by APS, to income-qualifying residential, nonprofit, and multifamily building owners. Participants receive monthly utility bill credits ($15-$30) in exchange for giving the utility access to the connected solar inverters.
- **Storage Rewards** program installs a behind-the-meter battery system at customer residences and provides them with a $500 incentive for granting the utility access to the battery. As the utility technically owns and operates the battery system, the customer receives onsite benefits of battery storage but does not pay operations and maintenance fees. Storage Rewards program customers are on time-varying rates, and APS manages the battery on their behalf. The batteries charge during low cost periods when solar generation is at its peak and discharge to help customers reduce grid strain and save on utility bills during peak periods.

APS operates its iDER programs using its DER management system (DERMS) platform, which manages devices from 11 different DER vendors. Together, these programs engage customers from a variety of segments and provide grid services including load curtailment and load shifting by monitoring the DER landscape and generating informed DER forecasts for proactive, DER-aware grid planning. APS harnesses DERMS-enabled situational awareness to optimize customer-owned devices, resulting in on-demand capacity to support the grid during peak periods; peak demand management to reduce grid strain; load shifting to harness

> *OEM APIs allow APS to manage DER actively to reduce their impact on the grid.*

low cost solar energy; and solar curtailment to ensure grid stability. OEM application programming interfaces (APIs) allow APS to manage DER actively to reduce its impact on the grid.

4.4 Technical Standards Considerations

Over the last decade, work on standards was focused on ensuring that DER connected to the grid does not pose a risk to the grid stability. Today, the standardization process is going beyond that and is increasingly focused on providing a communication layer that enables more complex interaction between DER and the grid.

For electrical equipment manufacturers and digital DER management tool providers, it is critical that their products support or are planning to support the following standards to remain relevant in the marketplace.

4.4.1 IEEE 1547-2018

This standard focuses on the technical specifications for and testing of the interconnection and interoperability between utility electric power systems and DER. It provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. It also includes general requirements, response to abnormal conditions, power quality, islanding, and test specifications and requirements for design, production, installation evaluation, commissioning, and periodic tests. These requirements are universally needed for the interconnection of DER to electric power systems at typical primary and secondary distribution voltages. DER include all synchronous machines, induction machines, or power inverters/converters and will be sufficient for most installations. The criteria and requirements are applicable to all DER technologies interconnected to electric power systems at typical distribution voltages. IEEE 1547-2018 represents a significantly enhanced performance and functional capability of DER connecting specifically to distribution systems. It includes performance capability categories and allowable ranges of functional settings that provide flexibility to align with specific system needs. The 2018 standard introduced the following key elements:

- Expanding the scope of the prior IEEE 1547 standard by considering bulk power system issues such as ride-through requirements as well as distribution system issues
- Extending requirements from the interconnection system and the individual DER unit to the whole DER facility
- Expanding the applicability beyond individual equipment such that it can be used for plant-level verification

- Specifying capabilities and functions necessary in a local DER communication interface (e.g., interoperability considerations) in addition to the electrical performance of the DER at its connection point.
- Enabling DER to have the capability of providing autonomous response to voltage and frequency changes to support the grid, including voltage regulation and frequency droop response

4.4.2 IEEE 1815 (DNP3)

The IEEE 1815-2015 standard established a standard for the communication media for most power communication systems. It specifies protocol structure, functions, cybersecurity features, and interoperable application options (subset levels), which are known as DNP3. The specified subset level defines the functionality implemented in each device. The simplest level is intended for basic devices. More advanced levels support increasing functionality. DNP3 is specified in IEEE 1547 as a standard of communication media.

4.4.3 IEEE 2030.5 (SEP 2.0)

The IEEE 2030.5-2018 standard is one of the most advanced DER management standards. This standard enables utility management of the end-user energy environment, including DR, load control, time of day pricing, distributed generation management, EV, etc. It includes the mechanisms for exchanging application messages, the exact messages exchanged (including error messages), and the security features used to protect the application messages.

4.4.4 UL 1741 (Inverter Performance Standards)

UL 1741 is a product performance standard that primarily covers the hazard component of the inverter function. UL standards generally address electrical, fire, and mechanical hazards as well as electrical ratings verification. UL 1741 also specifies the same interconnection performance requirements as IEEE 1547.

4.4.5 Smart Inverters (California Rule 21)

The CPUC regulates the largest rollout of DER in North America in the California ISO balancing area and sets the technical and commercial standards for DER interconnection and operation according to its Rule 21. The CPUC has implemented new technical standards for the DER systems that are intended to go beyond safety and hazard issues and “establish programmable functions” that DER systems will perform to support power system operations. The following autonomous inverter functionalities were added to the technical operating standards in Rule 21 in 2017:

- Support anti-islanding to trip off under extended anomalous conditions
- Provide ride-through of low and high voltage excursions beyond normal limits

- Provide ride-through of low and high frequency excursions beyond normal limits
- Provide volt/volt-ampere reactive (Volt/VAR) control through dynamic reactive power injection through autonomous responses to local voltage measurements
- Define default and emergency ramp rates and high and low limits
- Provide reactive power by a fixed power factor
- Reconnect by soft-start methods

4.4.6 OpenADR 2.0

Open Automated Demand Response (OpenADR) provides a nonproprietary, open standardized DR interface that allows electricity providers to communicate DR signals directly to existing customers using a common language and existing communications such as the internet. The OpenADR Alliance created several product profile specifications based on the OASIS Energy Interoperation Standard. The OpenADR 2.0a and b profile specifications provide specific implementation-related information to build an OpenADR-enabled device or system.

4.4.7 SunSpec Modbus

SunSpec Modbus is an open standard that specifies common parameters and settings for monitoring and controlling DER systems. SunSpec Modbus enables multi-vendor interoperability for manufacturers of solar inverters, energy storage devices, trackers, meters, and other DER devices. It is semantically identical and fully interoperable with the IEEE 2030.5 and IEEE 1815 communication protocols. SunSpec Modbus is specified in IEEE 1547 as a standard communication interface option.

SunSpec Modbus supports the concepts of use cases and profiles. For example, California Rule 21 is a use case for SunSpec Modbus. A California Rule 21 profile document specifies the SunSpec Modbus information models that are required to form a compliant interface for this use case.

Section 5
Acronym and Abbreviation List

API ... Application Programming Interface

APS ... Arizona Public Service

C&I ... Commercial and Industrial

CEC ... California Energy Commission

CO_2 ... Carbon Dioxide

CPUC ... California Public Utilities Commission

DDO ... Distribution Deferral Opportunity

DER ... Distributed Energy Resources

DERMS ... Distributed Energy Resource Management System

DNP3 ... Distributed Network Protocol 3

DOE ... Department of Energy

DR ... Demand Response

ESDER ... Energy Storage and Distributed Energy Resources

EV ... Electric Vehicle

FERC ... Federal Energy Regulatory Commission

GHG ... Greenhouse Gas

GMP ... Green Mountain Power

HVAC ... Heating, Ventilation, and Air Conditioning

iDER ... Integrated Distributed Energy Resources

IEEE ... Institute of Electrical and Electronics Engineers

ISO ... Independent System Operator

kW ... Kilowatt

MW ... Megawatt

NWA .... Non-Wires Alternative

NYISO .... New York Independent System Operator

OEM .... Original Equipment Manufacturer

OpenADR .... Open Automated Demand Response

PV .... Photovoltaic

RTO .... Regional Transmission Organizations

SCADA .... Supervisory Control and Data Acquisition

T&D .... Transmission and Distribution

US .... United States

VAR .... Volt-Ampere Reactive

Section 6
Table of Contents

Section 7
Table of Charts and Figures