GRIDWISE ALLIANCE

GRID INVESTMENTS TO SUPPORT FERC ORDER 2222

Technologies to Enable Aggregated DER Participation in Wholesale Power Markets

NOVEMBER 2023

ABOUT GRIDWISE ALLIANCE

GridWise Alliance leads a diverse membership of electricity industry stakeholders focused on accelerating innovation that delivers a more secure, reliable, resilient, and affordable grid to support decarbonization of the US economy. Our members believe that a modern grid is the critical infrastructure component of a decarbonized advanced economy.

For more information, please visit www.gridwise.org.

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EXECUTIVE SUMMARY

In 2020, the Federal Energy Regulatory Commission (FERC) issued Order 2222 to facilitate participation and promote competition in wholesale energy markets by removing barriers that limit how aggregated distributed energy resources (DERs) connect and contribute to wholesale energy markets overseen by Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs).

To support effective and efficient implementation of FERC Order 2222, it is essential that specific technologies are deployed in the grid infrastructure. This paper explores and outlines the grid technologies which are vital for DER aggregation and the various utility and customer-side products. Addressed are those unique to DER aggregation, such as Virtual Power Plants (VPPs) and DER Management Systems (DERMS). Other processes and technologies used and owned by utilities may support additional grid functions beyond supporting DER aggregation. These include: Advanced Integrated Planning, Load-DER Forecasting, Analytics Platforms, Advanced Distribution Management Systems (ADMS), Standard DER Integration, Voltage Optimization (VO), Geographic Information Systems (GIS), DER Submetering, Advanced Retail Billing, Automated Metering Infrastructure (AMI), and Communications (fiber and Field Area Network [FAN]).

Shorter- and longer-term benefits of deploying these various technologies in support of FERC Order 2222 are described in detail within this paper, explaining the purpose, benefits, and use of these technologies to support the order and additional implications and benefits to utilities, aggregators, and customers.

INTRODUCTION

In 2020, the Federal Energy Regulatory Commission (FERC) issued Order 2222 to facilitate participation of distributed energy resources (DERs) in wholesale energy markets managed by Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs).[1] The order states that DERs "may include, but are not limited to, electric storage resources, distributed generation, thermal storage, and electric vehicles and their supply equipment." These DERs are located on the distribution system, often behind the customers' meters. The power output from these devices may be too small to meet the minimum size requirements to participate in RTO/ISO bulk power markets. Aggregating these resources optimizes their combined power and capabilities for efficient grid integration and energy management.

The value of DER aggregation lies in its ability to unlock the full potential of decentralized energy resources and promote a more flexible and resilient energy system. Through aggregation, DERs can be coordinated and controlled as a single entity, allowing for optimized power generation, improved grid stability, and enhanced integration of renewable energy sources.

Aggregated DERs can provide various grid services, such as frequency regulation, voltage support, and peak power demand management. The aggregated resources can be dispatched across both the distribution and transmission grids in response to system needs, providing additional capacity and flexibility to the power system. Aggregation enables the efficient management of variable generation and demand, facilitating the balancing of electricity supply and demand in real-time. DER aggregation will also provide a new revenue stream for DER owners.

Realizing the benefits of aggregated DERs to the distribution and bulk power systems will require the deployment of technologies that provide aggregators and grid operators visibility into the availability and condition of DERs and allow for real-time control and management of the power moving onto the grid. These advanced technologies will require new communication and data management systems, as well as new tools for forecasting and planning.

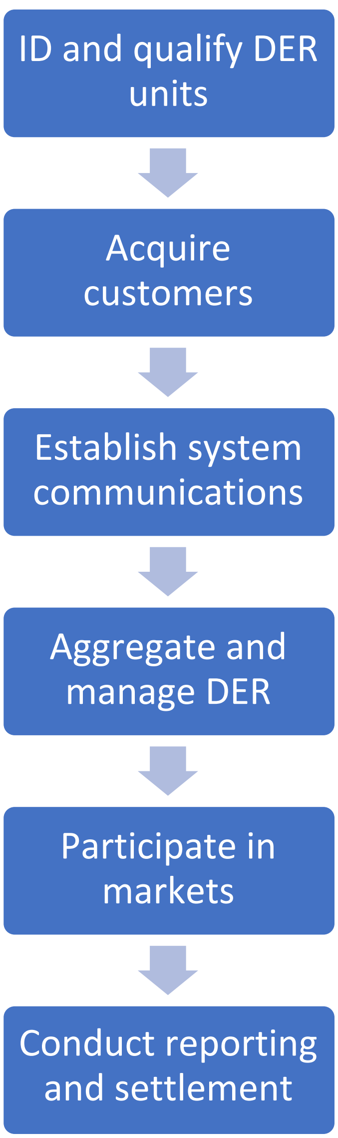
Since the issuance of FERC Order 2222, industry attention has been focused on how rules and schedules for RTO and ISO implementation are developed, with less focus on the distribution system technologies necessary to connect retail customers to the wholesale market. Full implementation of FERC Order 2222 will require deploying grid technologies to enable new business models, market designs, and system operations.

This paper describes the grid technologies that are key to increasing levels of DER aggregation to allow for wholesale market participation. Furthermore, these technologies go beyond mere compliance with the order and offer an opportunity for grid operators to achieve improved benefits versus costs, compounding functional benefits for grid operators.

[1] Docket No. RM18-9-000 E-1_0.pdf (ferc.gov)

DER AGGREGATION PROCESS

The owners of individual DERs participate in regional energy markets indirectly. The direct market participant—the entity that acquires, manages, and sells the output of DERs into the market—is referred to as the DER aggregator, which could be either a distribution utility or an independent third party. Whether conducted by a utility or a third party, the aggregation process involves the following steps:



Identification and qualification of eligible DER units: Aggregators identify and verify the eligibility of the DER units based on their capacity, location, and technical requirements.

Customer acquisition: Aggregators identify and contract with customers for their aggregated power services. This could include establishing contracts to provide energy to the bulk power system, working with local customers interested in procuring DER renewable generation, and collaborating with local distribution companies.

Installation and commissioning of communication devices: Aggregators install communication devices on each DER unit to collect performance data and status in real-time.

Aggregation and management: Aggregators use software and communication technologies to aggregate the DER units and manage their performance as a single entity. This involves monitoring and optimizing the performance of each unit based on grid requirements and market conditions.
Participation in energy markets: Aggregators participate in energy markets to sell excess energy and provide ancillary services such as frequency regulation, voltage support, and reactive power.

Reporting and settlement: Aggregators provide regular reports to the grid operator on the performance of the DER units and receive payment for the services provided.

Each step in the process of aggregation is supported by both hardware- and software-based technologies to provide visibility, with most deployed by the distribution utility. Third party aggregators will also need technologies to manage DERs under contract.

Wholesale power markets and DER participation

Wholesale electricity markets allow for the purchase and sale of the large quantities of electricity that move across high-voltage transmission lines. The electricity produced by large power plants, and increasingly, renewable energy facilities, is sold to utilities, which then distribute it to consumers. Wholesale electricity markets allow utilities to make purchases from multiple suppliers, ensuring a reliable and affordable supply of electricity to consumers. These markets are regulated by FERC and are operated by Independent System Operators (ISOs) and Regional Transmission Operators (RTOs).

Power markets are designed to trade power for certain time intervals or to trade specific grid services, but only two—day-ahead and ancillary services markets—are appropriate for DER aggregation. Day-ahead markets are used to buy and sell electricity scheduled for delivery the following day. Market participants submit bids and offers for electricity based on their anticipated needs and production capabilities. These bids and offers are used to set the day-ahead market clearing price, which is the price at which all electricity is bought and sold for the following day. Day-ahead markets allow for some level of near-term predictability and balance the forecasting ability of aggregators with the predicted load needs. Ancillary services markets are used to buy and sell services that support the operation of the electric grid, such as frequency regulation, voltage control, and reactive power. These markets are critical to maintaining the reliability of the electric grid and ensuring that it can respond to changing conditions in real-time. Ancillary services markets represent an opportunity for DER participation through the unique grid management capabilities of DERs, particularly energy storage solutions.

FERC ORDER 2222 REQUIREMENTS

FERC Order 2222 requires RTOs and ISOs to revise their market rules and create new participation models to enable DERs to participate in wholesale markets on a level playing field with traditional generators.

These new market participation models must offer comparable treatment to traditional generators, ensure the reliability of the grid, and protect the interests of all market participants. Additionally, the new models must be designed to facilitate the participation of DERs in the wholesale markets by allowing aggregators to sell the energy produced by the DERs to the wholesale market.

Another requirement of FERC Order 2222 is that RTOs and ISOs must ensure that DERs are able to participate in the wholesale markets in a way that does not compromise the reliability or stability of the grid. This is particularly important given the potential variability and intermittency of certain DERs, such as solar and wind resources. To meet this requirement, RTOs and ISOs must develop methods to forecast and manage the output of DERs, as well as establish appropriate performance standards for DERs to ensure they can operate reliably and safely.

FERC Order 2222 also requires RTOs and ISOs to ensure that DERs are fairly compensated for their participation in the wholesale markets. This includes establishing clear and transparent pricing mechanisms that reflect the value that DERs provide to the grid. DERs can offer a variety of services, including energy, capacity, and ancillary services, and RTOs and ISOs must ensure that these services are appropriately valued and compensated.

To meet the requirements of FERC Order 2222, RTOs and ISOs must also address several technical and operational issues related to the integration of DERs into the wholesale markets. For example, they must establish protocols for the communication and control of DERs, including the ability to curtail or ramp up their output as needed. They must also ensure that DERs comply with all relevant standards and regulations related to grid operation, cybersecurity, and safety.

While larger electric utilities, primarily Investor-Owned Utilities (IOUs), will have to work with RTOs and ISOs to support compliance with Order 2222, FERC has issued a determination that allows some utilities to opt out. Customers of utilities that distributed four million MWh or less in the previous year may choose not to participate in DER aggregations if the relevant regulatory authority prohibits wholesale market participation. This provision mostly applies to municipal and rural cooperative utilities.

Finally, to comply with FERC Order 2222, RTOs and ISOs must engage with stakeholders to ensure that the new market participation models are developed in a transparent and collaborative manner. This includes consulting with DER aggregators, utilities, and other market participants to identify potential participation barriers and address any concerns that arise.

TECHNOLOGIES TO SUPPORT DER AGGREGATION

To support the complex, decentralized, and varying operating characteristics of DERs in an aggregation scheme, hardware and software technologies and procedures are required to ensure reliable and efficient operation. These technologies support communication and analysis of data, enhance grid operations, provide system visibility, and allow for system-wide management of DERs. This section includes descriptions of essential hardware and software grid components that must be deployed by distribution utilities or aggregators to connect customer DERs to the bulk power markets via aggregation when FERC Order 2222 is fully implemented.

The proliferation of DERs across the distribution system, and the aggregation of DERs for participation in wholesale markets, requires better DER load forecasting and a more holistic planning process across the grid. These software-enabled processes are as important to the effective implementation of FERC Order 2222 as the technologies discussed in this paper. Longer descriptions of each technology and process can be found in the Technology Primer section of this paper (see Table 1).

	Technology	Grid Function	Deployed By
Digital Hardware	**Advanced Meter Infrastructure**	A series of technologies including a smart meter and its attendant supporting systems that allow for two-way communication between the customer point of service and the utility.	Distribution Utility
	Smart Inverters	Due Changes the direct current from solar panels to alternating current used by consumers and has communication and control capabilities to help manage power quality on the grid.	Distribution Utility
	DER Submetering	Due to the unique nature of DERs compared to typical consumer load, FERC Order 2222 requires separate metering for distributed generation and storage.	Distribution Utility
	Voltage Optimization	Manages voltages within service limits due to power injections from generator sets or solar photovoltaic generation (PV), withdrawals for charging of batteries and EVs, and sudden load switching such as some cases with demand response and EVs.	Distribution Utility
	Broadband Communication and Field Area Network	High speed, high bandwidth communications between grid devices is a foundational capability to allow for reporting and control between ISOs, substations, utilities, and aggregators and their grid devices.	Distribution Utility
Software-Based Grid Components	**Distributed Energy Resource Management System (DERMS)**	A platform to dispatch each individual DER.	Aggregator
	ADMS	Host applications that collect data and evaluate and mitigate DER impacts on power flows; and utilize DERs for distribution benefits.	Distribution Utility
	GIS	Aggregation requires GIS tracking to locate DERs on the network.	Distribution Utility
	VPP		Aggregator
	Analytics Platform	Optimizes the use of DERs for supplying distribution-level services.	Distribution Utility
	Advanced Retail Billing	In the case of customers with DERs, retail bills must be adjusted for net of wholesale market participation of aggregated DERs to avoid double rewarding.	Distribution Utility
Technology-Enabled Processes	**Advanced Integrated Planning**	Permits the distribution utility to evaluate the impact of DERs on distribution infrastructure planning.	Distribution Utility
	DER Load Forecasting	Provides the ability to avoiding double counting DERS.	Distribution Utility

Grid Components (Digital Hardware)

Automated Metering Infrastructure (AMI): AMI is a series of technologies including a smart meter and its attendant supporting systems that allow for two-way communication between the customer point of service and the utility. AMI supports FERC Order 2222 via several features including tracking customer interval net load data to assemble forecasts adjusted for DERs, real-time data acquisition of total and DER submeter data, frequency and voltage rapid response, support for control and dispatch of DERs. Additionally, AMI supports decentralized and autonomous operations at the grid edge perform safety and reliability operations such as autonomous disconnect and reconnect.

DER submetering: Due to the unique nature of DERs compared to typical consumer load, FERC Order 2222 requires separate metering for distributed generation and storage. This allows for monitoring of net production of DERs and feeds into calculations that determine participation and appropriate compensation for individual DER contributions.

Smart Inverters: Smart inverters are essential components of electric DER aggregation as they enable grid operators to manage the output of renewable energy sources. They provide advanced functionality such as reactive power control, voltage regulation, and frequency support, which are critical for maintaining grid stability and reliability.

Voltage Optimization (VO): VO is needed to manage voltages within service limits due to power injections from generator sets or solar photovoltaic generation (PV), withdrawals for charging of batteries and electric vehicles (EVs), and sudden load switching such as some cases with demand response and EVs.
Broadband Communication and Field Area Network (FAN): High speed, high bandwidth communications between grid devices are a foundational capability to allow for reporting and control between ISOs, substations, utilities, and aggregators and their grid devices. Devices such as sensors, meters, and controllers are installed on each DER unit to collect data on their performance and status, which is transmitted to the aggregator's control center through communication networks such as cellular, satellite, or wireless. The Field Area Network (FAN) enables communication with these grid edge devices. The communications and devices themselves included embedded, advanced security to prevent cybersecurity breaches. Edge devices can inter-communicate between their electrical peers to validate sometimes-inaccurate GIS information about device siting. These devices need to support interoperability to work in concert and to integrate with current and future systems.

Software-Based Platforms

DER Management System (DERMS): DERMS is a software platform that enables the aggregation and management of DER units as a single entity. It provides real-time monitoring, forecasting, and optimization of DER units based on grid requirements and market conditions. DERMS also enables the participation of DER units in demand response programs and energy markets. In addition to DERMS for aggregators, distribution utilities will also eventually need to integrate their own DERMS system or interface with aggregators to make use of DERs for distribution-level services.

Geographic Information System (GIS): While many distribution utilities track utility-owned assets using GIS systems, adequate support for DER aggregation requires GIS tracking to locate DERs on the network.

Virtual Power Plant (VPP): VPPs integrate and coordinate multiple DERs into a unified and flexible network. The primary purpose of VPPs is to optimize the collective operation of these diverse DERs, enabling them to function as a single, controllable entity. By aggregating and managing a multitude of DERs, VPPs can respond to fluctuations in electricity demand and supply in real-time. They can adjust the output of renewable resources based on weather conditions, manage energy storage systems to balance the grid during peak demand periods, and activate demand response measures to reduce consumption at times of stress on the grid. VPPs provide grid operators with greater control and visibility, allowing them to integrate higher levels of intermittent renewable energy, minimize curtailment, and ensure a reliable and secure electricity supply.

Analytics Platform: An analytics platform is needed to optimize the use of DERs for supplying distribution-level services. This platform includes data and applications that come from an Advanced Distribution Management System (ADMS). Examples of data and information provided include power quality performance, grid model validation, reliability and capacity planning, situational awareness data showing the state of DERs, and outage prediction information. Many analytics platforms perform a capital planning function, but some utilities may need to provide additional justification to account for these technology investments as Capital vs. Operational Expenditures.

Advanced Retail Billing: In the case of customers with DERs, retail bills must be adjusted for net of wholesale market participation of aggregated DERs to avoid double rewarding (based on submetering and demand response measurement and verification algorithms).

Software-Enabled Processes

Advanced Integrated Planning: The integration of the customer, the distribution system, and the transmission/bulk power system will require better planning and forecasting of DERs and the grid upgrades to accommodate these new resources to benefit both the distribution and transmission systems. Advanced Integrated Planning permits the distribution utility to evaluate the impact of DERs on distribution infrastructure planning, both in terms of avoided infrastructure as well as needed investments. This provides utilities with full insights into the impacts of these DERs on the system while taking full advantage of the additional capacity they provide to the system. Technologies that support planning include analytics platforms as well as financial modeling and forecasting tools.

DER Load Forecasting: FERC Order 2222 contains provisions that specifically address the requirements that aggregators do not double-count DERs as they bid into the wholesale energy market. Therefore, distribution utilities require advanced forecasts of the gross (not net) load of aggregated DERs, thus avoiding double counting (and double rewarding). Utilities use technologies such as analytics platforms (described below) and advanced retail billing systems to perform DER forecasting and to ensure accurate measurement of DER load.

DEPLOYMENT TIMELINE FOR TECHNOLOGIES TO SUPPORT FERC ORDER 2222

Compliance with FERC Order 2222 and taking full advantage of the opportunities that DER aggregation presents requires significant technology investment by utilities, ISOs, RTOs, and aggregators. This investment will necessarily come over time and in response to new DER deployments. The integration of this technology will also vary regionally as each ISO works through adjustments to its own DER aggregation rules and requirements to align them with FERC Order 2222.

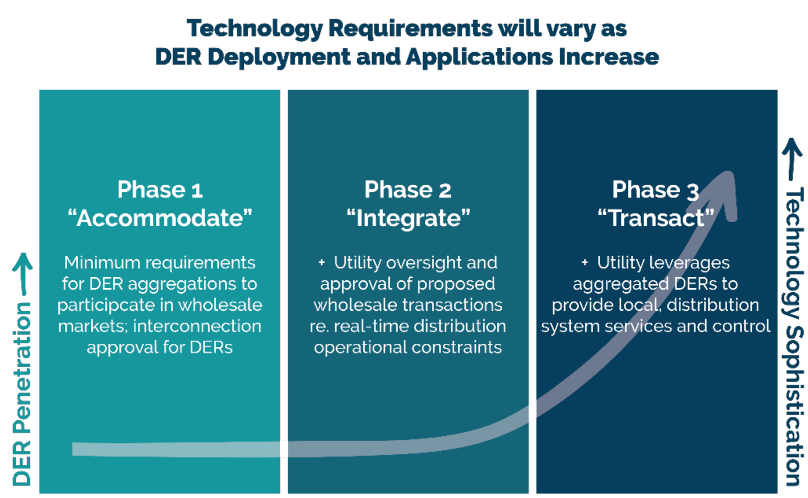


Figure 1: GridWise Alliance Maturity Phase model for adopting FERC 2222 supportive technology.

There is no single technology deployment pathway to full implementation in support of FERC Order 2222. The path depends on each utility's unique environment, the number of retail customers, and the ISO or RTO's interpretation of FERC Order 2222 requirements and the region's own ability to support integration. This multi-path approach can be broken into phases that account for the level of DER penetration in a given service territory as well as technological sophistication. This technological evolution can be broken into three phases: 1) Accommodate, 2) Integrate, and 3) Transact. Progression through these phases will occur at differing paces between ISO regions and even within each region as utilities experience varying rates of DER penetration and existing regulations support DER aggregation adoption at differing levels.

Accommodate

During the "Accommodate" phase, utilities invest in and deploy technologies that allow for a variety of load and supply conditions. This is aligned with typical distribution utility systems that may be conservatively overbuilt to support worst-case scenarios such as extreme high load days or disruptive events such as storms. This approach may lead to an ultimate denial of DER interconnection applications in areas where the grid cannot support the additional load. Or the utility may require the owner of the DER to make further investment in the grid to support this additional load. This phase requires little or no intelligence and automation technologies for the system to operate other than basic communications, protection, and metering. Under this phase, advanced communication between DERs and various support technologies are used to coordinate visibility and control. Management and control of these grid edge resources supports functions such as reducing impact to the grid, reducing peaks, reducing losses, alleviating capacity issues, improving voltage profiles, conserving energy, and maximizing DER connections.

Integrate

Under this phase, advanced communication between DERs and various support technologies are used to coordinate visibility and control. Management and control of these grid edge resources supports functions such as reducing impact to the grid, reducing peaks, reducing losses, alleviating capacity issues, improving voltage profiles, conserving energy, and maximizing DER connections.

Transact

During the transact phase, utilities and third-party aggregators fully participate in the wholesale power market. This phase is marked by full recognition that DERs can provide significant value to the grid both within the local distribution network as well as on the bulk power system. Systems that promote DER aggregation and market participation lead to further development of DERs thanks to improved economies but require optimization to support grid reliability and resilience. This phase leads to the Distribution System Operator (DSO) model in which adds system operator functions traditionally found at the ISO level and applies them to the distribution system.

BEYOND TECHNOLOGY: OTHER CONSIDERATIONS

Technology investment and adoption is only part of the solution to achieving the vision and full compliance with FERC Order 2222. Improved processes, methods, and operating models that support ISO interpretation of the order are all required.

Market Interface

To bid into wholesale power markets, aggregators may need to meet certain technical and operational requirements, as defined by the ISO and RTO overseeing the wholesale market in their region. These requirements include registration and qualification standards as established by the ISO or RTO including technical capabilities, performance standards, data reporting, market monitoring, and compliance obligations.

Policy Needs

Under FERC Order 2222, utilities and states retain responsibility for processes enabling safe and reliable DER grid connections. However, both have a role in interpreting and complying with the implementation requirements of the order within their ISO and RTO region. A notable challenge includes creating clear rules around issues associated with double counting services to ensure that participants are not compensated twice for the same service. For example, if a customer has a behind-the-meter DER, such as a solar panel, that is compensated for the power it produces and the same power is also used to reduce the customer load, this DER would be double counted. In this case, solar power serves as both a supply resource and a load reduction. Addressing this and related issues can be addressed through policies implemented by the utility.

Standards

Standards are important for ensuring the interoperability and compatibility of distributed energy resources (DERs) across different regions and markets. These standards define the technical requirements and specifications that are needed to enable DERs to participate in wholesale energy markets and provide grid services but given the evolving nature of DERs, aggregation, and the unique requirements of various ISOs and RTOs, these standards will take some time to achieve.

The development of DER aggregation standards represents an opportunity for collaboration between industry stakeholders, including utilities, regulators, and technology providers. As utilities consider AMI system upgrades or new AMI adoption, consideration should be given to new standards and specifications for AMI and related communications, security protocols, and meter devices to include support for DERs and compliance with FERC Order 2222.

Compounding Benefits of Technologies

Many of the grid enabling technologies that allow for compliance with FERC Order 2222 offer additional benefits beyond participation in the wholesale power market and support for the order. Investments in these technologies allow aggregators or utilities to apply multiple features of the technologies to improve reliability, decrease O&M, increase resilience, and improve services for customers.

Examples include:

- Analytics Platforms: In addition to DER integration planning and associated benefits to support the order, various analytics platforms offer utilities with recommendations to optimize existing assets or to improve overall capital and load planning.
- Advanced Metering Infrastructure (AMI): Utilities seeking two-way communication with customer meters that allow for remote meter reading look to AMI as a solution. In addition to meter reading benefits, AMI supports remote connect/disconnect and creates a foundation to support IoT connectivity and advanced features that support behind-the-meter DER and EV growth.
- Distributed Energy Resources Management Systems (DERMS): DERMS offers aggregators and utilities the ability to monitor DER conditions to analyze capacity and contributions to the grid. While critical to support interfacing with the ISO or RTO, DERMS also provide grid operators with monitoring and forecasting ability to assist with local distribution (and transmission) operations.

FINAL THOUGHTS

A variety of evolving grid technologies are necessary to support DER aggregation and compliance with FERC Order 2222 implementation. In addition to ensuring FERC Order 2222 compliance, many of these technologies provide further benefits to grid operators and customers. Implementing these technologies not only allows for fair participation of DERs in wholesale markets, fostering competition, but also creates a more resilient grid for future generations.

Further Reading

Summary of Expert Recommendations for Supporting DER Aggregator Participation in Wholesale Markets and Operations in Line with FERC Order 2222 https://pubs.naruc.org/pub/0827C24C-C7BE-D081-5317-6E2C90DEC3C2?mc_cid=5843747e55&mc_eid=4e32dbe81d

TECHNOLOGY PRIMERS

The following pages provide more information on the technologies necessary to fully implement FERC Order 2222 as referenced in this document. Details provided include an overview of the topic as well as grid functions and requirements to implement the solution to support the order.

CONTENTS

Advanced Metering Infrastructure | Distribution Utility

ABOUT THIS TECHNOLOGY

Advanced metering infrastructure (AMI) refers to a measurement and data collection system that includes a smart meter at the customer site, the communication network transmitting and receiving data to and from the electric service provider, and the management system used by the electric service provider to operate the grid and send signals to the customer meter. Fundamentally, AMI provides a mechanism for two-way electricity flow and communication between edge devices on the distribution system. The trend in the AMI industry is to leverage more standardized "internet of things" (IoT) connectivity models and support edge intelligence for more efficient and proactive monitoring and decision-making, as well as enabling the grid to accommodate distributed energy resources (DER) and electric vehicle (EV) growth.

USE IN THE MODERN GRID

Real-time information flow is essential to monitoring distributed energy assets and power quality as energy transactions and controls take place. AMI 2.0 is considered the next phase of adoption by utilities and applies 15 years of learning from AMI 1.0 to the Modern Grid. With metering technology now including enhanced energy measurement capabilities combined with dedicated edge processing, waveform data captured in the millisecond refresh times can be utilized at the edge for more consumer awareness of energy use, grid diagnostics, and anomaly detection. These capabilities enable expanded use cases for transactional DER and EV monitoring and energy management.

AMI solutions provide:

- Data that feeds the "knowns" for decision-making and managing load vs. demand balancing.
- Interval data for customer and net load is needed to assemble load-serving entity (LSE) forecasts adjusted for DERs.
- Frequency and voltage rapid response capabilities.
- Autonomous operations at the edge for safety and reliability (to embed centralized orchestration capabilities) and provide for individual home and DER optimization.
- Autonomous disconnect/reconnect at the edge.
- Waveform-level accuracy to support edge control and dispatch, including demand response programs.
- Real time load disaggregation to identify, visualize, and manage loads, including DERs.
- Enhanced outage and fault identification and communication with customers.
- Support for time-varying rates, including demand response programs targeted at DERs.

Advanced Metering Infrastructure | Distribution Utility

PHYSICAL LOCATION

AMI sensor and control hardware exists on the edge and throughout the distribution grid. Head-end systems and meter data management systems exist in the cloud and utilize the data for billing, grid management, and consumer engagement efforts.

WHAT CHANGES ARE NEEDED TO SUPPORT FERC ORDER 2222?

Recent innovations in AMI have significantly improved grid sensing and energy management capabilities. Real-time high-speed processing of substantial data derived from waveform data (AC variation over time) allows for enhanced safety, analytics, and control capabilities. Enhanced visibility and control at the grid edge supports decision-making, grid planning/forecasting, asset optimization, and orchestration.

TECHNOLOGY DEPENDENCIES

Recent innovations in AMI have significantly improved grid sensing and energy management capabilities. Real-time high-speed processing of substantial data derived from waveform data (AC variation over time) allows for enhanced safety, analytics, and control capabilities. Enhanced visibility and control at the grid edge supports decision-making, grid planning/forecasting, asset optimization, and orchestration.

FOR MORE INFORMATION

National Grid AMI Grid Edge Computing Report, March 2022.
https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={E-82D4A60-4DDD-4D91-BA89-1EE17574D2DC}

Smart Inverters

ABOUT THIS TECHNOLOGY

Smart inverters are essential components of electric DER aggregation as they enable grid operators to manage the output of renewable energy sources. They provide advanced functionality such as reactive power control, voltage regulation, and frequency support, which are critical for maintaining grid stability and reliability.

USE IN THE MODERN GRID

Virtually all transmission and distribution power lines are alternating current (AC), and electricity can flow directly to consumers for use in homes and businesses. However, the power produced by solar panels is direct current (DC) and requires an inverter to convert the electricity to AC before it can be used by the consumer or moved onto the grid.

Conventional inverters shut down if the voltage or frequency on the grid fluctuates, even over a small range, preventing electricity from DERs from moving past the inverter. This can have a cascading effect on grid stability, as more inverters sense tiny disturbances and shut down the flow of DER power to the grid. Another weakness of a conventional inverter is that during power outages, a conventional inverter prevents the consumer from using the power generated by DERs.

Smart inverters, with advanced software and two-way communication with the grid, can autonomously react to even small fluctuations of grid conditions and allow consumers to use power from DERs at all times. Furthermore, these services like voltage and frequency regulation, ride-through capabilities, dynamic current injection, and anti-islanding functionality to maintain power quality across the grid.

PHYSICAL LOCATION

Smart inverters are located on the consumer’s side of the meter and will increasingly be incorporated directly into new DERs.

WHAT CHANGES ARE NEEDED TO SUPPORT FERC ORDER 2222?

New technical standards and codes for DERs will require that all grid-connected DERs have the ability to provide grid reliability functions and two-way communication. State public utility commissions and other regulators must incorporate these standards into their interconnection processes to ensure the adoption of smart inverters.

As smart inverters proliferate, grid operators will need a better understanding of the interactions between multiple smart inverters, as well as the impacts of smart inverters on the overall distribution system. The widespread deployment of smart inverters that can inject power onto the grid will require strong coordina-

Smart Inverters

As smart inverters proliferate, grid operators will need a better understanding of the interactions between multiple smart inverters, as well as the impacts of smart inverters on the overall distribution system.
The widespread deployment of smart inverters that can inject power onto the grid will require strong coordination with the utility to ensure safety and allow grid operators to manage power flow to prevent disruptions. The potential for a malicious actor to manipulate power from DERs through smart inverters to damage the system or disrupt power will require new cybersecurity requirements for DERs.

TECHNOLOGY DEPENDENCIES

Advanced metering infrastructure must be connected to a communications network, either through the internet with a secure gateway or directly with a utility communications system.

DER Submetering | Distribution Utility

ABOUT THIS TECHNOLOGY

Distributed Energy Resource (DER) submetering is an electric consumption and production monitoring system that is connected behind the traditional electric meter at each customer's premises. DER submetering is required to distinguish the energy transacted in wholesale markets from the customer's baseline energy consumption purchased at retail prices. Typically, a separate communications-capable submeter is required for distributed generation, storage, and electric vehicles (with discharge capability) participating in aggregations. Demand response and energy efficiency DERs that provide energy via net load reduction rather than injections or withdrawals of power can only be "measured" by subtracting the customer's metered load from an established baseline consumption level using various estimation techniques.

USE IN THE MODERN GRID

DER submetering is deployed and operated by the distribution utility, often purchased and installed at aggregator or customer expense. Meter data is used by aggregators for wholesale billing and by distribution utilities to adjust retail billing accordingly. Using DER submetering, the energy output of each DER can be accurately measured and tracked. This enables the aggregation of DERs into a Virtual Power Plant (VPP), which can then participate in wholesale electricity markets. DER submetering allows for the verification and validation of energy generation and consumption from DERs, ensuring accurate accounting and fair compensation for their contributions to the grid. It provides transparency and reliability in measuring the performance and output of individual DERs, which is crucial for their integration into wholesale markets under FERC Order 2222.

FERC Order 2222 requires that aggregated DERs be allowed to participate in transactions at wholesale rates, without double counting or doubly rewarding them for their participation. To avoid doubly rewarding DERs for their output, it must be added back into the customers' metered load for retail billing purposes. Likewise, energy consumed for recharging storage must also be accounted at wholesale rates and excluded from the retail bill. Similarly, to avoid double counting the DER's output, the distribution utility must adjust its net load forecasts and demand bids to the ISO markets upward to account for the DER's output. Likewise, the ISO must bill it for wholesale energy consumed at that adjusted load, since the DERs are being cleared and paid by the wholesale market separately from the distribution utility load.

PHYSICAL LOCATION

This technology is set behind the customer meter, measuring the DER's energy production (and, for batteries, recharging energy) so that it can be distinguished from the total (net) customer consumption.

DER Submetering | Distribution Utility

WHAT CHANGES ARE NEEDED TO SUPPORT FERC ORDER 2222?

To enable compliance with FERC Order 2222, specific changes in DER submetering may be necessary. Some key changes that might be required include:

- Granular Data Collection: DER submetering systems may need to collect more granular data regarding energy production or consumption at the individual DER level. This could involve deploying advanced metering infrastructure (AMI) or upgrading existing submetering systems to capture more detailed information.
- Time Synchronization: FERC Order 2222 emphasizes the need for accurate time synchronization among DERs participating in aggregation. As a result, DER submetering systems would need to ensure precise time synchronization across all submeters to facilitate proper coordination and reporting.
- Data Reporting and Communication: Submetering systems may need to incorporate standardized protocols for data reporting and communication, enabling seamless integration with RTOs or ISOs. Compliance with specific data formats or communication protocols specified by the relevant market entity may be required.
- Verification and Validation: DER submetering may require mechanisms for verifying and validating data from individual DERs. This could involve incorporating data quality checks, audit trails, or independent verification processes to ensure accuracy and reliability.
- Aggregation Capabilities: To participate in wholesale electricity markets under FERC Order 2222, DER submetering systems should support the aggregation of individual DERs into a VPP. This entails the ability to aggregate and aggregate performance data from multiple submeters and provide a consolidated view of the VPP's energy contributions.
- Improved Communications: Typical AMI metering intervals may suffice for wholesale energy market transactions. Telemetry over internet connections may be sufficient rather than over AMI networks, which typically do not have the bandwidth for real-time communications with large numbers of devices. While very short-term measurement intervals on the order of a few seconds may be required to support ancillary service market transactions. These requirements are dependent on the implementation plans that are, to some degree, specific to each ISO. It is possible that low-cost metering and telemetry could be supported by existing or modified technology inside solar PV and battery inverters.

TECHNOLOGY DEPENDENCIES

For DER submetering to be implemented in support of FERC Order 2222, AMI meters or inverter-based measurements that offer secure internet telemetry will be needed.

Voltage Optimization | Distribution Utility

ABOUT THIS TECHNOLOGY

Distribution voltage control involves strategies used to maintain acceptable voltage levels at all points along a distribution feeder under all loading conditions to ensure that the voltage delivered to consumers remains within acceptable limits. This technology enables voltage stability, which is required to maintain optimal power quality and minimize energy losses.

Substation adjustments are often made using seasonal rules of thumb based on experience, engineering analysis, and the measured output voltage. Absent sensing and communications to capacitors located along the feeder, voltage levels are often set manually and on a seasonal basis. Improvements in Advanced Metering Infrastructure (AMI) technologies have enabled voltage optimization at the edge by providing real-time voltage readings at meter end points. Distributed energy resources management systems (DERMS) have further provided capabilities in voltage optimization leveraging real and reactive power capabilities of distributed energy resources (DERs).

USE IN THE MODERN GRID

FERC Order 2222 is expected to result in significant penetration and engagement of many types of DERs via aggregators in wholesale markets in Phase II. Advanced Volt-var Control (VVC) will be needed to manage voltages within service limits due to highly variable power injections (generators, PV solar, batteries), withdrawals for charging (batteries & EVs), and sudden load switching (demand response, EVs). It will also be needed by distribution utilities exercising their oversight role to justify any refusal for proposed DER wholesale transactions due to violations of voltage constraints. In Phase III, distribution utilities will integrate aggregated DERs into their VVC systems to leverage their capabilities to help manage voltage, allowing higher rooftop solar hosting capacity and preventing undue deterioration on tap changers and capacitor banks due to rapid switching.

PHYSICAL LOCATION

Control equipment is at the head of each service feeder in distribution substations and, increasingly, downstream along the feeder and embedded in customer DERs in the future. Voltage optimization algorithms are also commonly run centrally with the advanced distribution management system (ADMS) or in the enterprise or cloud for DERMS.

Voltage Optimization | Distribution Utility

WHAT CHANGES ARE NEEDED TO SUPPORT FERC ORDER 2222?

Simple historical voltage control is a nearly universal utility practice. In order to make this technology capable of supporting FERC Order 2222, more automated and capable control, known as Volt-var Control, will be required. As penetrations of DERs increase, increased power flows and resulting voltages will be much more variable and rapidly volatile. Power flows and voltage profiles may even reverse during periods of high DER output. With proper communications, sensors, and controls, the DERs' output can be coordinated to manage voltage under all conditions.

TECHNOLOGY DEPENDENCIES

The technology required to support the implementation of voltage optimization is extensive, beginning with communications technology such as supervisory control and data acquisition (SCADA), DERMS, and AMI. Voltage-controlling assets will also be essential, including load tap changers, capacitors, voltage regulators, front-of-meter, and behind-the-meter DERs.

Supplying historical metered data as well as real-time voltage and power factor readings from end-of-feeder meters will be necessary using AMI systems. In addition, the use of Geographical Information Systems (GIS) will supply connectivity and coordinates of lines, equipment, customers, and DERs.

In conjunction with these technologies, digital twin simulations, advanced control algorithms, and intelligent software may be necessary to assist in the implementation of voltage optimization in support of FERC Order 2222.

CASE STUDIES

There are many example deployments by distribution utilities, but likely most or all fall short of utilizing DERs as part of the solution rather than just the source of the problem.

FOR MORE INFORMATION

MODERN DISTRIBUTION GRID (DSPx). Volume II: Advanced Technology – Maturity Assessment. Version 2.0. (November 2019). https://gridarchitecture.pnnl.gov/media/Modern-Distribution-Grid_Volume_II_v2_0.pdf

Uluski, B. (2011). *Volt/VAR Control and Optimization Concepts and Issues.* Electric Power Research Institute. https://nwess-archive.ece.uw.edu/2012/talks/uluski.pdf

Communications (Fiber + FAN) | Distribution Utility

ABOUT THIS TECHNOLOGY

Communications networks provide the backbone for transmitting information about the distribution system. Field Area Networks (FANs) define the "last mile" connectivity to a wide array of end devices. Real-time communications are critical to integrating distributed energy resources (DERs), managing load, automating distribution processes, diagnosing, and locating grid issues, and supporting other smart grid functions. The main trunk communication from FANs to other parts of the network (communication backhaul) is accomplished over fiber optic cabling systems.

USE IN THE MODERN GRID

Fiber and FANs are foundational for communications with the independent systems operator (ISO), substations, and aggregators, including:

- Embedded security with device-specific keys to prevent cybersecurity breaches, especially important in a high-DER future.
- Awareness of edge devices to understand their electrical peers – to validate GIS information which is not always accurate (to support accurate dispatch).
- Interoperability (communication protocols and API's) to integrate with a variety of systems and future technologies across multiple vendors of hardware and software is critical to minimize implementation cycle times and promote reasonable cost models while increasing operational flexibility and technology adoption rates over time.
- Evolving connectivity standards away from proprietary models via industry coordination in the cellular (e.g., LTE, LTE-M, NB-IoT) and mesh field area network (e.g., Wi-SUN, Wi-Fi) connectivity models for last mile ubiquitous IoT coverage, has opened substantial opportunity for orchestrated use of unprecedented, segmented bandwidth allocations and edge device processing capabilities.
- Flexibility to cost effectively deploy devices in an ad hoc or saturated network connectivity model has opened more opportunity for shortening ROI across all potential use cases. (e.g., AMI, SCADA, DC, street lighting, etc.)

PHYSICAL LOCATION

Components of the communications network are dispersed throughout the distribution system. Examples include embedded radio devices in hardware, devices connected via wire to field hardware, pole-mounted network gateways and collectors, and data held in the cloud.

Depending on the connectivity model utilized, network infrastructure could be deployed as a cellular tower, using FAN devices such as repeaters and gateways supporting an extended mesh connectivity footprint, or direct connectivity to an optical fiber feed.

Communications (Fiber + FAN) | Distribution Utility

WHAT CHANGES ARE NEEDED TO SUPPORT FERC ORDER 2222?

Technologies are currently capable of supplying the connectivity required by FERC Order 2222 and continue to evolve through wireless bandwidth allocation and expanded coverage. Given the divergence of IoT standards in place on the grid, multiple connectivity models must be supported to orchestrate the real-time transactional requirements of the Order. This flexibility will allow operators to address variable geographic topologies, technologies, and operating conditions while promoting DER aggregation.

TECHNOLOGY DEPENDENCIES

To build stable real-time data flows for monitoring and control of utility grid-level infrastructure, sufficient promotion, allocation, and standardization of proven and reliable connectivity models are needed. These include LTE/LTE-M/NB-IoT for backhaul and IoT device level connectivity and unlicensed, IP standards-based (Wi-SUN) affordable area network mesh connectivity. Additionally, there is a need for premises connectivity via Wi-Fi between the advanced smart meter and storage battery, EV charger, home appliance, or specific load control devices. All of these different levels of connectivity models present future potential for interoperability required to satisfy FERC Order 2222.

USE CASE EXAMPLE

A utility covers a 3,000 square mile area and has over 80% of service addresses within municipal areas that include dense populations and high-rise buildings. Coverage to both dense and more rural areas requires cost effective implementation strategies and without saturation of available IoT connectivity platforms. (e.g., cellular saturation in any single area of city). The utility desires 100% coverage of total grid assets under connectivity models available. Using a balanced approach with four types of IP based and industry standard connectivity models offers interoperability, broad coverage capability, and flexibility for applying rapid deployment of strategic ad hoc use cases vs. structured blanket deployment. For example, the utility could choose a mix of Cellular, Wi-SUN, Wi-Fi, and Fiber. In the dense city areas, deploying an IP based mesh connectivity model is justified, based on smart city infrastructure which can be serviced under a utility owned or contracted managed services network. However, less dense areas do not offer the same justification for a full network build-out. As such, cellular data connectivity can be applied to provide more economical coverage. In either case, data is reported to a single head end application which uses industry standard integration methods for data and command exchange with various utility systems either via MDMS or direct with each application. Using this approach, the goal of 100% connectivity to all edge devices is achieved economically and reliably by using common utility industry-standard connectivity models, which benefit from large existing component supply ecosystem, cost, and coverage efficiencies.

ADDITIONAL RESOURCES: 3GPP Initiative: https://www.3gpp.org/
Wi-SUN Alliance: https://wi-sun.org/ | Wi-Fi Alliance: https://www.wi-fi.org/
Fiber Network Alliance: https://www.fibernetworkalliance.com/about/

Distributed Energy Resources Management System | Aggregator

ABOUT THIS TECHNOLOGY

A distributed energy resources management system (DERMS) is a software platform that monitors, forecasts, controls, and coordinates a variety of distributed energy resources (DERs), including generation, storage, and loads, such as solar, wind, battery storage, smart thermostats, and electric vehicle (EV) charging. As the impacts of DERs are broad, DERMS can often take various forms, such as an aggregation service over a large fleet of DERs, customer engagement services to maximize the value of their DERs, a utility grid management and orchestration system, a utility program management system, a virtual power plant (VPP) aggregating DERs for wholesale or distribution level markets and programs, and a field level automation controller for fast and resilient local grid management. Demand response management systems (DRMS) can be seen as a subset of DERMS for load management.

USE IN THE MODERN GRID

DERMS, with its many capabilities, is a necessary component to enable FERC Order 2222. Core use cases include DER aggregation, forecasting, DER asset management, VPP services for market participation, and ensuring the grid is safe, reliable, and resilient for DERs under various levels of market participation. DERMS can also support aggregation of DER types and vendors.

PHYSICAL LOCATION

This technology is implemented via software systems that can be cloud-based, on-site, or decentralized across the grid.

WHAT CHANGES ARE NEEDED TO SUPPORT FERC ORDER 2222?

In addition to DERMS, to support DER participation in wholesale markets, a wholesale market management system with utility advanced distribution management system (ADMS) software for grid-safe market participation is required. Additionally, systems that support DER aggregation such as virtual power plant services will be needed. Coordination between these systems — often owned and operated by different entities — is complex and will require these organizations to share plans for integration and communication of systems going forward.

TECHNOLOGY DEPENDENCIES

For DERMS to be implemented in support of FERC Order 2222, DER communications (e.g., IEEE2030.5) and ADMS are needed.

Advanced Distribution Management System | Distribution Utility

ABOUT THIS TECHNOLOGY

Advanced Distribution Management Systems (ADMS) are software platforms that integrate numerous data sources and host operational tools for distribution management to optimize system performance. An ADMS can collect, organize, display, and analyze real-time or near real-time information about the electric distribution system, which allows operators to plan and execute complex distribution system operations to increase system efficiency, optimize power flows, maintain reliability, and prevent overloads.

USE IN THE MODERN GRID

ADMS is needed, as DER penetration and impacts become significant, to host applications that 1) collect data and evaluate and mitigate DER impacts on power flows, and 2) utilize DERs for distribution benefits. With increased participation of DER aggregators, ADMS will be needed to evaluate the safety and reliability impacts for proposed day-ahead operating schedules for the next 24 hours. ADMS provides analysis to ensure that the proposed DER schedule and real-time operations do not conflict with operational constraints, scheduled outages for maintenance, branch circuit overloads, and voltage violations.

PHYSICAL LOCATION

The software platform may be centrally located at the utility's control center with its various dependent components spread across the footprint of that utility.

WHAT CHANGES ARE NEEDED TO SUPPORT FERC ORDER 2222?

ADMS with its many capabilities is a necessary component to enable FERC Order 2222. Core use cases include DMS, FLISR, DERMS, CVR and VVO – all aimed at ensuring the grid is safe, reliable, and resilient for DERs under various levels of market participation.

Critical and necessary capabilities include integration of DER status and power flows, offers, and bids into the wholesale day-ahead and real-time markets, Eventually, offers to provide distribution-level services from DER aggregators will be needed for FERC Order 2222 compliance.

TECHNOLOGY DEPENDENCIES

A variety of technologies are required or enhance the benefit of ADMS including:

- GIS (geographical information systems) supplying connectivity and coordinates of lines, equipment, customers and DERs
- Electrical topology model
- Data models

Advanced Distribution Management System | Distribution Utility

- Communications systems
- Distribution SCADA for integration of sensor data
- AMI systems that supply historical metered data and real-time voltage and power factor from end-of-feeder meters
- PI data historians to support forecasts, model calibration, and planning
- Customer Information System (CIS)
- DERMS to provide data on DERs and access to DER controls

CASE STUDIES

SDG&E implemented its ADMS in 2012, enabling electronic workflow for tracking system upgrades, enhancing outage identification and customer notifications, and improving overall situational awareness capabilities in the Electric Distribution Control Center. Since then, SDG&E has continued to improve features such as simulating the impact of residential solar output on the Electric Distribution System, creating situational awareness for wildfire risk areas, and creating the ability to automate some levels of Fault Location, Isolation, and Service Restoration (FLISR) technology, also known as self-healing circuits.

CenterPoint Energy's ADMS system recognizes faults on the system, sectionalizes feeder circuits through intelligent grid IT sensors and helps route crews efficiently when there is a disruption. The DSCADA system allows CenterPoint dispatchers to communicate with 2,000 intelligent grid switching devices and other automated switching devices on the system. The back-office system can communicate in real time to those devices and recover power more quickly by automatically restoring service under some conditions and minimizing the extent of any disruption requiring a truck-roll.

ADDITIONAL RESOURCES

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Geographic Information Systems | Distribution Utility

ABOUT THIS TECHNOLOGY

A Geographic Information System (GIS) connects or "georeferences" general map elements of geographically dispersed infrastructure to their geo-physical locations. Electric utilities use specialized GIS to display distribution systems and circuits located from substations down to customers, often superimposed with roads, pipelines, and other relevant infrastructure data. GIS provides the ability to geographically assess not only locations, but the vast amount of data tied to the map layers, including attributes such as operational and maintenance status and histories. With this methodology, utility GIS can subsume the role of older asset management and facilities management systems. GIS is used by system operators as a source of information for scheduling and conducting maintenance, energizing and deenergizing switching circuits, dispatching field crews, and in outage management and recovery. It is also used to supply predictive data for system planning and expansion.

USE IN THE MODERN GRID

GIS is used widely today by large and medium-sized utilities as a foundational capability of a modern (smart) grid. GIS provides an integrated basis for managing infrastructure, thereby improving reliability and lowering costs for operations and maintenance. Smaller utilities are adopting GIS at a slower rate simply due to the cost and complexity of establishing its use. GIS capabilities will need to be extended to accommodate distributed energy resources (DERs) resulting from FERC Order 2222 and other initiatives.

PHYSICAL LOCATION

GIS databases and software reside on the utility's back office and control-room computer networks. The GIS displays produced are used by distribution dispatchers in control rooms.

WHAT CHANGES ARE NEEDED TO SUPPORT FERC ORDER 2222?

As a result of increased DER penetration, the capabilities of utility GIS will need to incorporate the locations, status, and characteristics of DERs on the distribution system, including their participation in an aggregation scheme. This will be a critical function to create comprehensive power system models of an increasingly complex distribution system for planning and analysis. GIS data and modeling will provide the basis for accommodating DERs in dynamic protection schemes, FLSIR, volt-VAR optimization (VVO), and other advanced operational applications.

Geographic Information Systems | Distribution Utility

TECHNOLOGY DEPENDENCIES

For GIS to be implemented in support of FERC Order 2222, expanded data, georeferenced features, and other attributes will need to be collected and incorporated. GIS is often used in conjunction with distribution management systems (DMS/ADMS) as the basis for their display and in distribution supervisory control and data acquisition (D-SCADA) systems when present for remote actuation of switches, breakers, and more. It is often tied to customer information systems (CIS) and outage management systems (OMS). As DERs are incorporated in GIS, GIS will use the aggregators' distributed energy resources management systems (DERMS) as a source of DER status and characteristics information.

CASE STUDIES

CenterPoint Energy's GIS data and display are integrated with the distribution management system (DMS) in its distribution system control center.

More information can be found at:
https://gis.centerpointenergy.com/outagetracker/?WT.ac=OC_Image_Callouthttps://gis.centerpointenergy.com/outagetracker/?WT.ac=OC_Image_Callout

FOR MORE INFORMATIONF

A The Future of GIS. T&D World, Sept. 2018
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Virtual Power Plant | Aggregator

ABOUT THIS TECHNOLOGY

Virtual power plants (VPPs) utilize digital technology to integrate multiple decentralized energy resources into a single network. VPPs allow for the aggregation and coordination of various energy sources, such as solar panels, wind turbines, battery storage systems, and even demand response programs, to function as a unified power plant. Through advanced software systems and real-time monitoring, VPPs can optimize the dispatch and distribution of electricity, effectively balancing supply and demand, and maximizing the utilization of renewable energy sources.

Virtual power plants offer numerous benefits, including enhanced grid stability, increased renewable energy integration, improved energy efficiency, and the potential for demand-side management, ultimately contributing to a more sustainable and resilient energy system.

USE IN THE MODERN GRID

VPPs are being adopted as more DERs are deployed throughout service territories and regions. At their core, VPPs provide aggregation services to allow grid operators better insight and management of multiple resources by treating them as a unified entity.

PHYSICAL LOCATION

VPPs offer a form of aggregation that allows for dispatch of power (as a traditional power plant would) to the grid. Software used to perform VPP services is typically owned by the aggregator, and most often are cloud-based. Using a network of communication connections to DERs, the VPP monitors generation among disparate resources and gives the aggregator the ability to dispatch energy as required to meet energy demands or wholesale contractual obligations.

WHAT CHANGES ARE NEEDED TO SUPPORT FERC ORDER 2222?

VPPs are designed to support aggregated generation, so are, at their core, critical system components to support FERC Order 2222. As each ISO or RTO may interpret FERC Order 2222 rules in different ways, VPPs participating in each region may have to meet certain wholesale market communication and integration requirements.

TECHNOLOGY DEPENDENCIES

Since they serve as aggregation solutions for DERs, VPPs require available generation (DERs) and networked communication connections to monitor generation from these resources. Additionally, complex software and control schemes are required to operate the system. Unlike relatively straightforward control systems found in legacy power plants, VPPs must be capable of handling the complexity of integrated many distributed energy sources, control those sources and sufficiently respond to demand signals and direction to deliver power at required capacities, when needed.

Virtual Power Plant | Aggregator

CASE STUDIES

Arizona Public Service (APS) developed a VPP design using various strategies to optimize energy management. One goal was system peak reduction, which involved advanced load dispatch technology to efficiently shed load within the utility's time of use pricing structure, with pre-cooling strategies tailored for this purpose. Another goal included load shifting and duck curve management which prioritized charging during peak solar production periods and utilized thermal and battery energy storage to reduce peak demand. Additionally, the project aimed to provide backup power through battery energy storage to ensure continuity during grid outages, contributing to enhanced energy efficiency and grid resilience.

SMUD reviewed and presented a variety of VPP pilots and projects during a 2021 EPRI conference. Findings included a need for substantial investments in foundational technologies; the lack of standard communication protocols between utilities and DER aggregators presents a major challenge; and the cost associated with managing DERs through aggregators can strain project economics for utilities. Furthermore, the review identified a pressing need for standardized solutions, such as gateways and site controllers, to seamlessly integrate various DER types with VPP operations.

ADDITIONAL RESOURCES

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Virtual Power Plants. Energy.gov. (n.d).
https://www.energy.gov/lpo/virtual-power-plants

Analytics Platform | Distribution Utility

ABOUT THIS TECHNOLOGY

Analytics platforms improve operations and planning of distribution assets using grid data. A wide variety of applications and use cases are available through analytics, including proactive identification of overloaded and underused devices, capacity planning to address bottlenecks, distributed energy resources (DER) integration planning, voltage performance, and transformer asset health. By processing existing and past data, analytics platforms can predict future trends and inform cost-effective improvements and new system designs.

USE IN THE MODERN GRID

A Modern Grid is a known and connected grid that can adapt and react to new energy sources and sudden unexpected changes. These capabilities are essential for sustainable economic growth with built in adaptability. As energy sources outside the traditional generation and distribution model continue to expand, regulating bodies and utilities that promote sustainability and efficiency require the support of wider capabilities of data processing and analysis across the grid.

Analytics platforms are needed to optimize the use of DERs for supplying distribution-level services. They are fed by data and applications from Advanced Distribution Management Systems (ADMS) and provide insights such as power quality performance, grid model validation, asset information, reliability and capacity planning, and situational awareness. Analytics platforms support improved DER planning such as optimizing storage placement, supporting PV integration, calculation of risked voltage fluctuations or reverse power flow, hosting capacity support, and outage prediction.

PHYSICAL LOCATION

Analytics systems are typically located in the cloud. Cloud storage, data availability, and data security are critical for the confident and timely consolidation, access, and presentation of data by various edge applications and software applications used to monitor, manage, and execute transactional DER use cases.

WHAT CHANGES ARE NEEDED TO SUPPORT FERC ORDER 2222?

To make this technology capable of supporting FERC Order 2222, specific analytics packages must support a variety of utility and customer assets and rules interpretations unique to each ISO or RTO. This points to the need to leverage common integration standards to define data formats and improve implementation and operation efficiency.

Analytics Platform | Distribution Utility

TECHNOLOGY DEPENDENCIES

Analytics platforms are reliant on data from monitored systems. Distribution system sensors must collect data transmitted to head-end systems that process and sort data. Additionally, edge sensor and control devices with edge intelligence support, IP standardized connectivity models for ease of deployment, and common data exchange models for various software application sharing of data will be required. While sensor and edge devices have proliferated into the utility market sector and broader IoT market sector in recent years, the utility sector suffers from multiple connectivity model choices at varying stages of maturity and sometimes proprietary and integration costs. Breaking this limitation on the utility supply and demand market domain is key to advancing true common grid interoperability for the goal of FERC Order 2222 of transactive energy equality.many distributed energy sources, control those sources and sufficiently respond to demand signals and direction to deliver power at required capacities, when needed.

Advanced Retail Billing | Distribution Utility

ABOUT THIS TECHNOLOGY

Advanced retail customer billing systems include the capability to adjust retail (net) customer bills based on metered consumption to accurately represent gross customer bills. This net calculation and ability to track production and consumption support FERC Order 2222's requirement for accurate tracking of generation and load.

USE IN THE MODERN GRID

FERC 2222 requires that aggregated DERs be allowed to participate in transactions at wholesale rates without double counting or doubly rewarding them for their participation. To avoid doubly rewarding DERs for their output in the form of reduced net customer loads and hence lower (or negative) retail bills, their output must be added back into the customers' net metered load for retail billing purposes. Likewise, energy consumed for recharging storage must also be accounted for at wholesale rates and excluded from the retail bill.

PHYSICAL LOCATION

This technology is located on software and databases on utility billing system servers.

WHAT CHANGES ARE NEEDED TO SUPPORT FERC ORDER 2222?

Advanced retail billing is accomplished by adding sub-metered DER output to the customer-metered consumption. In some cases, such as demand response and energy efficiency DERs, production is estimated using a baseline measurement and verification method. This data is then used to recompute the retail bill. To support this method, sub-metering, valid baselines, communication systems, and the underlying advanced retail billing algorithms and systems are required.

TECHNOLOGY DEPENDENCIES

For advanced retail billing to be implemented in support of FERC Order 2222, DER submetering is required to supply the necessary data.

Advanced Integrated Planning | Distribution Utility

ABOUT THIS TECHNOLOGY

Advanced Integrated Planning refers to the business policies, methods, processes, data, assumptions, and tools to integrate the planning functions across Distribution, Transmission, and Energy Supply (Generation and/or Market) to enable timely, efficient, and effective system and resource planning for the interconnection of DER assets.

USE IN THE MODERN GRID

The proliferation of DERs across a utility's system, whether driven by FERC 2222 or not, requires system planning to take on a more holistic perspective to enable efficient interconnection and operational integration. This advanced integrated perspective enables the utility to identify, manage, and mitigate DER-driven operational issues or constraints across Distribution, Transmission, and Energy Supply (Generation and/or Market).

To simply meet current and projected system challenges, critical business capabilities such as planning, grid modernization, and supply / storage asset development must be transformed into highly coordinated, data-driven, transparent, cross-functional processes. The enhancement and integration of planning activities are foundational to enabling this process.

PHYSICAL LOCATION

Planning is typically handled by the engineering resources / departments of the utility.

WHAT CHANGES ARE NEEDED TO SUPPORT FERC ORDER 2222?

Advanced Integrated Planning requires modern planning application software capable of accurately modeling the entire energy system, from supply assets (including DERs) to Transmission and Distribution system assets, and even behind the meter assets. The planning application software must support the use of 8760 forecasting of load and supply requirements across individual phases and at a granularity of a line segment. The core basis of these forecasts is typically AMI hourly interval data. These requirements enable effective planning for all DER interconnection types, from Transmission-level to single-phase distribution. accuracy.

TECHNOLOGY DEPENDENCIES

Implementing successful Advanced Integrated Planning depends on several technologies and components:

- 8760 forecasting capability for load and supply
- GIS connectivity model
- Asset nameplate data for all assets (including non-utility DER assets)
- Business agreement data for all supply assets (detail operational constraints and capabilities)

Load DER Forecasting | Distribution Utility

ABOUT THIS TECHNOLOGY

Forecasting involves methods to predict and anticipate operating conditions for the future. Forecasting time horizon and frequency are determined by their use cases, typically from minutes and hours to days and weeks ahead for operational planning, and months to decades ahead for long term capital planning. Forecasting parameters are most commonly operational parameters such as weather, as well as load and DER (Distributed Energy Resources) status, power, energy, voltage, and current.

USE IN THE MODERN GRID

Forecasting grid operations is becoming more unpredictable with variable loads (e.g., EV charging), storage, and generation, as well as extreme weather patterns. The ability to forecast grid behavior accurately, automatically, at scale, at different levels and various time frames with confidence is becoming the starting point to managing adequacy, power quality, reliability, and resiliency. Forecasting can be performed at all levels from wholesale market, transition, and distribution, as well as individual and aggregated loads and DERs. Forecasting accuracies can also be translated into confidence levels. Analytics can further be used to augment directly measured parameters, such as forecasting grid power flow, as well as native vs. net load prediction. Forecasting systems are commonly integrated into operational systems (AEMS, ADMS), DER aggregation platforms, and asset management systems, as well as market management systems. Forecasts can be computed through various mathematical and machine learning techniques and are commonly used in market participation, generation and DER scheduling, and operational risk mitigation.

PHYSICAL LOCATION

Software systems can be cloud-based, on-premises, or decentralized across the grid.

WHAT CHANGES ARE NEEDED TO SUPPORT FERC ORDER 2222?

Forecasting is ready to support FERC Order 2222. It should be commonly and widely available for all parts of the energy system and ecosystem. With the rise of electric vehicles and the impact of their charging on the grid, they can become a valuable resource under FERC Order 2222, and advancements in EV charging forecasting, including traffic and charging patterns, will be needed.

Load DER Forecasting | Distribution Utility

TECHNOLOGY DEPENDENCIES

Include data for forecasting, such as sensor measurements, metering, and weather. To support load and DER forecasting, several system requirements must be met:

- Data Collection and Integration: The system needs to gather and integrate data from various sources, including historical load data, weather data, customer information, and DER characteristics. This data can come from smart meters, sensors, weather stations, customer databases, and other relevant sources.
- Scalability and Processing Power: Load and DER forecasting involve complex calculations and analysis. The system must have sufficient processing power and scalability to handle large volumes of data and perform computationally intensive algorithms in a timely manner.
- Advanced Analytics and Modeling: The system should employ advanced analytics techniques and forecasting models specifically designed for load and DER forecasting. This may include statistical methods, machine learning algorithms, time series analysis, and artificial intelligence techniques to capture patterns, correlations, and trends in the data.
- Real-time Data Updates: The system should support real-time data updates to ensure the most accurate and up-to-date forecasts. It should be capable of incorporating new data as it becomes available and adjusting the forecasts accordingly, providing timely insights to grid operators and energy managers.
- Integration with External Factors: Load and DER forecasting must consider external factors that influence energy consumption, such as weather conditions, holidays, events, and economic indicators. The system should be able to incorporate these factors and their potential impact on load and DER patterns.
- Visualization and Reporting: The system should provide visualizations, reports, and dashboards to present the forecasted load and DER data in a clear and understandable manner. This enables stakeholders to make informed decisions and take appropriate actions based on the forecasts.

ADDITIONAL RESOURCES

Cadeo Group. (2022). DER and Load Forecasting Considerations. Massachusetts Department of Energy Resources (Mass DOER).
https://www.mass.gov/doc/der-and-load-forecasting-considerations/download

EPRI. (2019). Forecasting for Load with High DER. U.S. Department of Energy (US DOE).
https://www.energy.gov/sites/prod/files/2019/08/f65/1.5.a.%20-%20SETO%20Modeling%20Workshop%20-%20EPRI.pdf