# TSO-DSO-Aggregator Market and Operational Coordination Requirements

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## Disclaimer



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# Introduction

More than half of U.S. states have pursued the use of distributed energy resources (DERs)[1] to provide services to manage the distribution grid through geotargeted DER programs, contracted services from third parties, and/or utility-owned battery storage systems (Figure 1).[2] Concurrently, a series of rulings by the Federal Energy Regulatory Commission (FERC), including Order No. 2222,[3] has continued to expand opportunities for DERs individually and through aggregations to provide alternatives to transmission investment and bulk power services. The result of these actions is the potential for DERs to provide both distribution services and wholesale services.

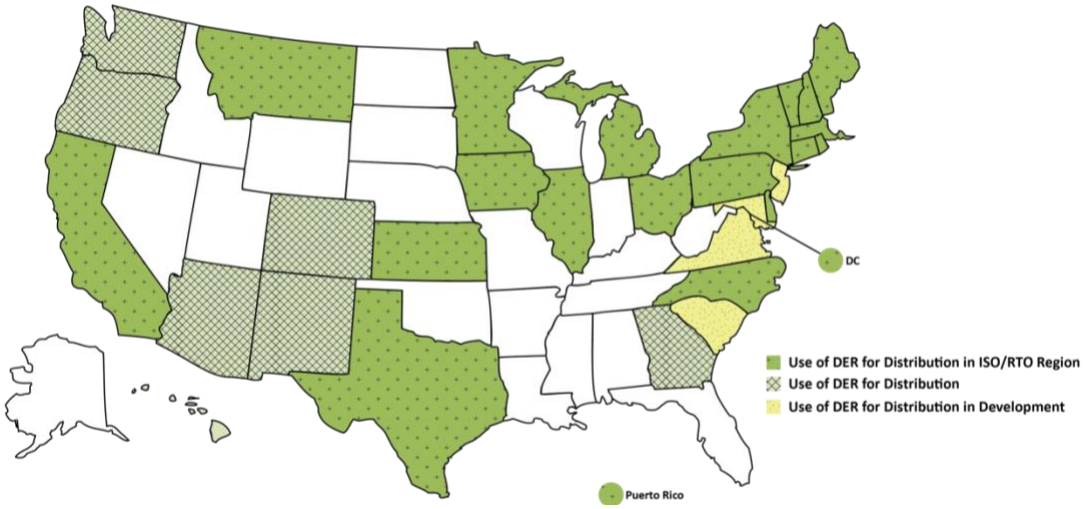


*Figure 1. DER Services for the Distribution Grid*

Order No. 2222 requires effective coordination of DER market participation and operational dual use of these DER services. The objective of coordination is to reduce the cost and complexity of providing grid services from DER aggregations while maintaining reliable system operation across both transmission and distribution systems.[4]

[1] DERs include electric storage, intermittent generation, distributed generation, demand response, energy efficiency, thermal storage, or electric vehicles and their charging equipment that are located on an electric utility's distribution system, a subsystem of the utility's distribution system, or behind a customer meter.

[2] This map includes states where utilities may own or contract DERs to manage distribution independent of required non-wire alternative processes. For example, Texas legislation allows distribution utilities to contract with a third party for battery energy storage systems.

[3] FERC Order No. 2222-B was issued June 17, 2021, and was effective August 27, 2021.

[4] EPRI, Coordination Frameworks to Meet the Needs of FERC Order No. 2222: An EPRI FO2222 Phase 1 Collaborative Report. https://www.epri.com/research/products/000000003002020593

The purpose of this paper is to foster a discussion among regulators, transmission system operators (TSOs),[5] distribution system operators (DSOs),[6] DER Aggregators,[7] and other stakeholders about the business requirements market and operational coordination—specifically, the requirements to enable the reliable and efficient use of DER services for both the bulk power system and distribution grid operations. This paper was informed by discussions with regulators, TSOs, distribution utilities, DER Aggregators, and technology solution providers. Additionally, this paper leveraged insights and analysis from current efforts to address similar needs in Australia,[8] Canada,[9] Europe,[10] and the United Kingdom.[11]

This paper describes the high-level business requirements and conceptual architecture for a scalable market and operational coordination (MOC) platform approach. A shared MOC platform provides a solution that accomplishes the following:

- Facilitates the dual participation of DERs in wholesale markets and distribution services, promoting flexibility and efficiency, and aligning with the requirements of FERC Order No. 2222.
- Enhances grid reliability as the scope and scale of DER services increase and participation becomes more diverse.
- Ensures adherence to federal and state regulatory requirements, enabling efficient and equitable participation of DER aggregations in the wholesale market and distribution services.
- Creates operational efficiency by streamlining coordination and communication among DERs, grid and market operators, and market participants, avoiding the complexity and cost of disparate systems.
- Supports the transition to a more distributed energy system,[12] accommodating new technologies that lower the barrier for participation to enable efficient market dynamics.

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[5] TSOs refer to all bulk power system operators, including independent system operators, regional transmission organizations, and other bulk power entities (e.g., balancing authorities), which source bulk power services from DERs.

[6] DSOs refer to the entities responsible for planning and operational functions associated with coordinating DER services for distribution networks and/or DER participation in wholesale markets in coordination with the TSOs, Aggregators, and other relevant parties. Utilities may serve as DSOs.

[7] A DER Aggregator is an entity that aggregates one or more aggregations of DERs for a market purpose. An aggregation of DER aggregations is defined as one or more DERs.

[8] Project EDGE Final Report, Version 1, Australian Energy Market Operator, October 2023. https://aemo.com.au/-/media/files/initiatives/der/2023/project-edge-final-report.pdf?la=en

[9] ICF, Development of a Transmission-Distribution Interoperability Framework, Independent Electricity System Operator, Ontario, Canada, 2020. https://www.ieso.ca/-/media/Files/IESO/Document-Library/White-papers/IESO-T-D-Coordination-Framework.ashx

[10] NordPool and Norwegian utility Agder Energi jointly developed a common platform, known as NODES™. https://nodesmarket.com/market-design/

[11] IBM, Flexibility Markets: Digital Design Study, Ofgem, 2022. https://www.ofgem.gov.uk/sites/default/files/2023-03/IBM%20Report%20-%20Digital%20Design%20Study.pdf

[12] DOE defines *distributed energy systems* as "a diverse array of generations, storage, and energy monitoring and control solutions that can be tailored to specific requirements and user applications, including cost reduction, energy efficiency, security of supply, and carbon reduction." https://www.directives.doe.gov/terms_definitions/distributed-energy-systems

Initial FERC Order No. 2222 compliance timelines may necessitate the use of simpler solutions to start. However, given the expected growth in the use of DER services for distribution, these initial simpler and/or ad hoc methods are unlikely to scale reliably. Given the time to develop a shared platform, jurisdictions may need to begin consideration now. As such, this paper includes recommended next steps toward potential development.

## Market and Operational Coordination Requirements

*Coordination is essential for ensuring bulk power system and distribution grid reliability, resilience, and the efficient utilization of DERs.*

A key step to enable coordination between TSOs and the associated DSOs and Aggregators is identifying the specific new and changed processes needed and the related requirements. This is particularly important for distribution utilities that are using DER services to manage distribution grids. This also is important for the Relevant Electric Retail Regulatory Authorities (RERRAs)[13] that will need to approve the utility costs associated with conforming to these new coordination requirements. Additionally, RERRAs have an oversight role regarding the DER tariffs and programs, as well as the distribution utilities' activities involved in the market and operational coordination.

### FERC Order No. 2222

FERC Order No. 2222 emphasizes the need for coordination between wholesale markets and the distribution use of DERs to facilitate the participation of DERs. Additionally, the order recognizes the importance of coordination between transmission and distribution system operators and RERRAs to facilitate the integration of DERs and DER aggregations in wholesale electricity markets. The key requirements in terms of market and operational coordination include the following:

- **Information Sharing and Data Requirements.** The order encourages coordination and information sharing among wholesale market operators, DSOs, Aggregators, and RERRAs. This is crucial for ensuring a clear understanding of the capabilities and characteristics of DERs, as well as compliance with relevant rules and regulations. This involves establishing protocols for the exchange of relevant data, such as DER locations, capabilities, and status, to enhance overall grid awareness and coordination and minimize cybersecurity and privacy concerns.
- **Market Rules Coordination and Participation Agreement.** FERC Order No. 2222 calls for coordination of market rules among the regional transmission organizations (RTOs)/independent system operators (ISOs), the Aggregator, and the distribution utility to ensure that the participation of resources in RTO/ISO markets does not present reliability or safety concerns for the distribution or transmission system. The order also emphasizes that, because individual resources in DER aggregations will likely fall under the purview of multiple organizations (e.g., RTOs/ISOs, RERRAs, distribution utilities), the Aggregator must attest that its aggregation is compliant with the tariffs

[13] RERRAs refer to entities that have jurisdiction over and establish prices and policies for providers of retail electric services to end-customers, such as the city council for a municipal utility, the governing board of a cooperative utility, the state public utility commission or any other such entity.

and operating procedures of the distribution utilities and the rules and regulations of the RERRA and the participating stakeholders.[14]

- **Avoidance of Double Compensation.** The order addresses the issue of double compensation, aiming to prevent Aggregators from receiving compensation in both wholesale and retail markets for the same services. Coordination among RTOs/ISOs, DSOs, Aggregators, and retail governance by the RERRA ensures that all individual resources in the DER aggregation are technically capable of providing services to the RTO/ISO through the Aggregator and are eligible to be part of the aggregation. This also provides an opportunity for distribution utilities to review the list of resources to assess whether they would be able to respond to RTO/ISO dispatch instructions without posing any significant risk to the distribution system and to ensure that these resources, which may be in other retail programs, do not receive dual compensation.[15]
- **DER Deliverability.** In addition to existing transmission assessment of deliverability, distribution utilities are now required to assess the deliverability of DER services from the grid edge to wholesale markets. These analyses assess the ability of the distribution system to host and integrate DERs without compromising reliability. The results of these analyses can inform decision-making regarding the integration of DERs into both transmission and distribution systems.
- **Operational Coordination.** The order directs grid operators to establish operational coordination mechanisms to manage the interactions between transmission and distribution systems in real-time operations. It requires establishing a process for ongoing coordination that addresses communications among the RTO/ISO, the Aggregator, and the distribution utility. The order also requires the Aggregator to report to the RTO/ISO any changes to its offered quantity (e.g., kilowatts) due to DER asset outages/curtailments. Furthermore, the order requires coordination protocols and processes for the operating day that allow distribution utilities to override RTO/ISO dispatch of a DER aggregation under circumstances where the override is needed to maintain reliable and safe operation of the distribution system.[16] This includes communication, control, and response protocols to changes in DER output or system conditions. For example, a distribution outage may prevent some DERs from being excluded from an aggregation, while DERs that are not affected by the outage can still participate.
- **Billing and Settlement Procedures.** FERC directs RTOs/ISOs to maintain coordination with distribution utilities and RERRAs to establish protocols for sharing metering and telemetry data to assist with settlements and audits of activity in all markets.[17] This involves establishing clear processes for tracking and compensating Aggregators for their participation and contributions to both markets while ensuring no dual compensation for the same service.
- **Consistent Treatment of Aggregations.** The order emphasizes the importance of treating DER aggregations consistently and seamlessly across wholesale and retail markets.

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[14] DOE FERC, Docket No. RM18-9-000; Order No. 2222, #339, Issued September 17, 2020. https://www.ferc.gov/sites/default/files/2020-09/E-1_0.pdf

[15] DOE FERC, Docket No. RM18-9-000; Order No. 2222, #281, Issued September 17, 2020. https://www.ferc.gov/sites/default/files/2020-09/E-1_0.pdf

[16] DOE FERC, Docket No. RM18-9-000; Order No. 2222, #310, Issued September 17, 2020. https://www.ferc.gov/sites/default/files/2020-09/E-1_0.pdf

[17] DOE FERC, Docket No. RM18-9-000; Order No. 2222, #271, Issued September 17, 2020. https://www.ferc.gov/sites/default/files/2020-09/E-1_0.pdf

- **Regulatory Oversight.** The order recognizes the key oversight role that RERRAs provide in market and operational coordination, such as setting retail rules related to DER tariffs, DER interconnection, data sharing, metering, and telemetry. This includes RERRA governance over DSOs' use of DERs for distribution grid services and the resolution of disputes between DSOs and Aggregators.

In summary, FERC Order No. 2222 promotes coordination among wholesale markets and distribution grid services and system operators to create a cohesive and supportive environment for the integration of DERs. This coordination helps to avoid regulatory conflicts, streamline market participation for Aggregators, and ensure fair compensation without double compensation for grid services. The order also aims to break down barriers and enhance coordination between transmission and distribution systems, recognizing that effective integration of DERs requires a comprehensive and collaborative approach across all levels of the electricity grid.[18] This coordination is essential for ensuring grid reliability, resilience, and the efficient utilization of DERs.

## Coordination Capabilities

Coordinated participation of DER aggregations in wholesale and distribution grid services involves a range of business capabilities and related requirements. The capabilities needed for market and operational coordination are informed by FERC Order No. 2222 directives, along with the implementation plans filed by each RTO/ISO. These implementation plans provide specific insights into how different regions envisage complying with the order, with some differences in proposed implementation approaches. However, any region/state outside of an RTO/ISO that is pursuing the dual use of DER services for both bulk power and distribution operations can consider these business requirements for application in their specific situations—for example, the Bonneville Power Administration's use of DERs for its needs and those distribution utilities pursuing distribution grid services within its balancing area.

In addition to reviewing FERC Order No. 2222 and RTO/ISO implementation plans, discussions with bulk system and distribution operators, regulators, and leading market and operational software providers offer helpful insights. Also, an examination of energy market structures and efforts to develop similar coordination platforms in Canada, the United Kingdom, Europe, and Australia provided additional context and learnings.

*Millions of DERs with changing relationships and operating conditions represent a much more dynamic dataset than the industry has had to manage to date.*

The following discussion is organized by three core functional areas: DER Registration, Market Coordination, and Operational Coordination. The discussion provides high-level, cross-cutting business requirements. Appendix A is a reference table of FERC Order No. 2222 requirements mapped to these requirements. They are a starting point for a deeper examination of detailed requirements that each DSO and RTO/ISO (or other bulk power entity[19]) will need in order to be implemented. A useful reference for understanding the specific information and data exchanges that may

[18] MISO Distributed Energy Resources Task Force 2024 Compliance Plan. https://cdn.misoenergy.org/2024%20Order%202222%20Compliance%20Framework631391.pdf

[19] The term *other bulk power entity* refers to those entities that source bulk power services to meet their responsibility to manage a portion of the bulk power system.

be involved is available in EPRI's DER Aggregation Participation in Electricity Markets report.[20] Overall, these requirements inform decisions regarding technology to enable the required functionality. The following section on coordination requirements provides the basis for the subsequent discussion on a shared MOC platform.

### *DER Registration*

DER registration is needed to facilitate the participation of individual and aggregated DERs in wholesale electricity markets and for retail/distribution grid services. This master record is a state or regional database for the management and dissemination of DER data. Registration involves cataloging DER data in a standardized manner, such as DER technical specifications, location, interconnection and operational constraints, performance characteristics, operational status, and mapping to related wholesale and retail aggregation rules. This ensures uniformity and aids in seamless integration.

*Interoperability and security are foundational to allow for smooth interactions with Aggregators, DSOs, and TSOs.*

Millions of DERs with changing relationships and operating conditions represent a much more dynamic dataset than the industry has had to manage to date. For example, homeowners will move and leave their solar and home batteries; however, they will take their electric vehicles with them. The grid locations of DERs will change as distribution feeders are reconfigured much more frequently than the bulk electric system. Therefore, DER registrations must have a robust change management process. This dynamic DER dataset is necessary for RTOs/ISOs, DSOs, and Aggregator systems for planning, operation, and settlement. As such, it needs to be secure and interface seamlessly with existing systems.

The Common Information Model (CIM)[21] represents a fully vetted and approved data standard for DER information that can significantly decrease the cost of system interfaces and data coordination. As shown in Figure 2, several stakeholders and systems require access to the master record of each DER and the related aggregations to effectively enable bulk power system market participation and provision of distribution grid services. Isolated efforts by any single group or function to address their information needs are prone to create barriers to the successful utilization of DER services.

[20] EPRI, DER Aggregation Participation in Electricity Markets, 2022. https://restservice.epri.com/publicdownload/000000003002020599/0/Product

[21] CIM provides a common definition of management information for systems, networks, applications, and services, and allows for vendor extensions. https://www.dmtf.org/standards/cim


*Figure 2. Uses of DERs and DER Aggregation Data*

Access to registration information to ensure data privacy is governed by specific privileges and rules established by FERC and/or the RERRA, as applicable. This ensures that entities such as Aggregators, TSOs, DSOs, regulators, and other authorized users can securely interact with the data. Transactions are logged and data are archived to maintain a historical record. Also, it is necessary to ensure data consistency and accuracy by including embedded approval functions for data entry and changes to maintain the integrity of the information. A coordinated effort between the main stakeholders and the RERRA is needed to establish data ownership and data governance frameworks. Interoperability is foundational to allow for smooth interactions with Aggregators, DSOs, and TSOs. Table 1 provides a list of high-level functionalities for DER registration as an initial set for further examination of needed business requirements.

*Table 1. High-Level DER Registration Functionality*

| ID | Functionality | Description |
|---|---|---|
| R1 | **Asset Registration** | DER Aggregator registers DER assets ("once"), including detailed technical specifications (asset type, location, size, and connection point) and ownership details common to all services and markets. |
| R2 | **Operating Parameters & Characteristics** | Details about the operational aspects of DER assets, including performance characteristics, metering, telemetry, and control capabilities. |
| R3 | **Interconnection and Operational Constraints** | DER interconnection and deliverability parameters, including interconnection requirements and any specific market access limitations (e.g., export limits and temporal constraints). |
| R4 | **DER Aggregation Information** | Detailed data about DER aggregations, including DER composition (e.g., flexible load, distributed generation, and battery storage) and aggregate operational characteristics. |
| R5 | **DER Aggregator & DER Owner Registration** | Registration of DER Aggregators and participating DER owners including relevant company information (e.g., ownership, contacts, and any required regulatory certifications). |
| R6 | **Bulk System Operator, Distribution Utility, and Retail Regulatory Jurisdiction Information** | Identification of relevant distribution utilities, retail regulatory jurisdiction/s, and wholesale market operators, including market and operational contact information and relevant market and operational rules, tariffs, and other information associated with the provision of DER services. |
| R7 | **Aggregation Rules and Market Participation Rules Pre-qualification** | Enable initial qualification based on wholesale and retail rules for aggregating DERs and provision of DER services for wholesale markets and/or distribution. |

As DERs—and their use—increase in retail and market programs, there also will be additional reporting requirements for Aggregators from the DSOs, RTOs/ISOs, and RERRAs, and federally from FERC and the North American Electric Reliability Corporation. DER registration and aggregation management can automate these functions and relieve administrative burdens for all stakeholders. As illustrated in Figure 3, several steps in the DER registration lifecycle can create administrative hurdles and potential data integrity issues if a single system of record is not used.

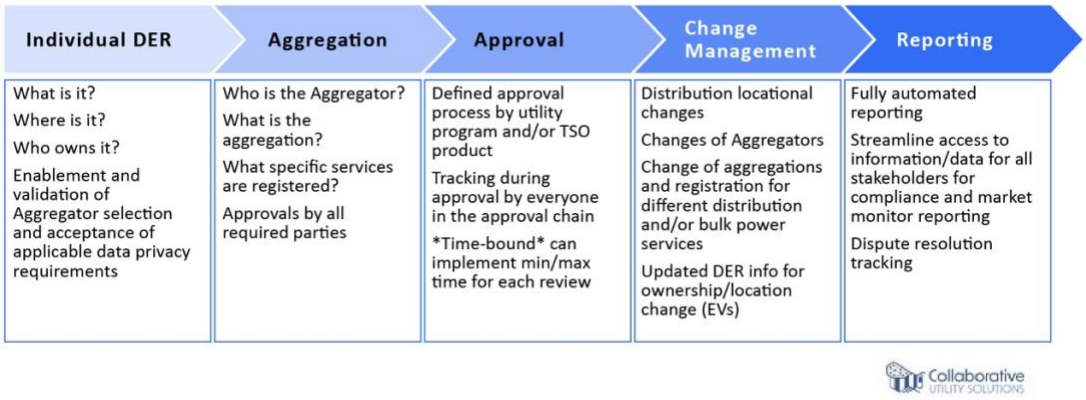


*Figure 3. DER Registration Administrative Process*

### *Market Participation Coordination*

Market participation coordination involves a set of mechanisms, processes, and technologies designed to facilitate the integration and participation of DERs. This functionality ensures that DERs, including individual and aggregated resources, can effectively and equitably participate in wholesale markets and distribution grid services. Aggregations allow for grouping multiple DERs into a single, manageable group

that is visible to both bulk power systems and distribution operators. Aggregation enables smaller DERs, which individually might not meet the minimum size requirements for market participation, to collectively participate in the wholesale market.

Market participation coordination includes the validation of Aggregators and their resource participation in the day-ahead market and submitted schedules, ensuring compliance with wholesale market and retail participation rules. This includes validation that the DER aggregation does not have a conflicting service commitment to the DSO. These validations leverage DER registration data. It also includes ensuring that Aggregators comply with market rules and regulations regarding bidding, scheduling, and dispatch processes. Figure 4 illustrates the process, indicating the level of complexity and number of interactions required. Detailed process mapping will be required to develop specific requirements for each platform implementation.

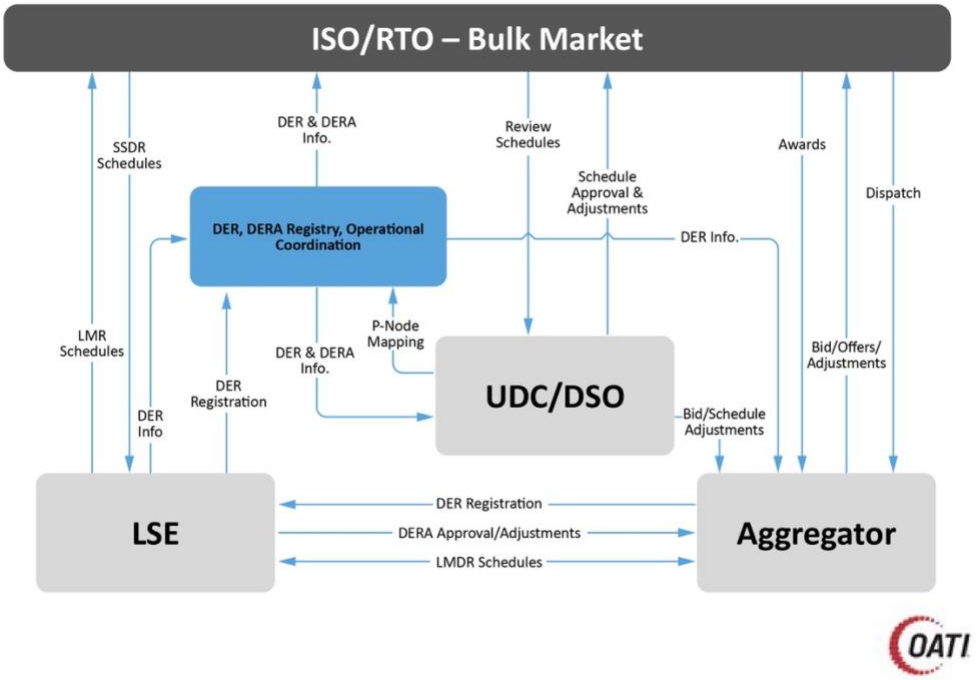


*Figure 4. Interactions of DER Registration and Market Coordination Processes*

*The real-time status of DER availability, capacity, and operational status is crucial for TSOs and DSOs to manage grid reliability and for the efficient dispatch of resources.*

Market coordination also involves awareness of the real-time status of DER availability, capacity, and operational status (e.g., outages, derations, curtailments). Real-time information exchange among Aggregators, TSOs, and DSOs is crucial for managing grid reliability and for the efficient dispatch of resources. In addition, market coordination capabilities support ongoing monitoring and reporting needed to ensure continuous compliance with FERC and relevant retail regulations. Market coordination also includes transaction records to support the resolution of disagreements or discrepancies among Aggregators, TSOs, and DSOs.

Market coordination requires a consistent assessment of DER performance for wholesale and distribution services for settlement purposes. This involves, for example, assessing individual DER performance by comparing retail metered data and baseline calculations against dispatch instructions and contractual obligations. This method is common to the provision of both wholesale and distribution services and can support the respective settlement processes. Table 2 provides an initial list of high-level functionalities for DER market participation coordination among a TSO and associated DSOs and Aggregators for further examination of the needed requirements.

*Table 2. High-Level Market Participation Coordination Functionality*

| ID | Functionality | Description |
|---|---|---|
| M1 | **DER Services Registration** | Register specific services offered by DER aggregations. |
| M2 | **DER Services Opportunities** | A list (or a map) with details on opportunities to provide wholesale and distribution services. |
| M3 | **Market Participation Rules Validation** | Validation to ensure DERAs adhere to specific market participation rules, such as bidding procedures, pricing structures, and pre-determined operational constraints. |
| M4 | **Dual Participation Validation** | Validation of DER participation in both retail and wholesale markets, ensuring there are no conflicts or issues arising from their dual involvement. |
| M5 | **Day-ahead Distribution Operator Validation of Wholesale Deliverability** | Distribution operator confirmation that DERs are capable of delivering on their wholesale market commitments. |
| M6 | **Automated Services Bidding** | Automated system for multiple wholesale market and distribution services bidding. |
| M7 | **DER State Information & Readiness** | Captures real-time information on the state and readiness of each DER, including its availability, current operating capacity, and potential issues affecting performance. |
| M8 | **DER Asset Outage & Curtailment Management** | Manages DER asset outages and curtailment including derations, notification procedures, and coordination of response strategies. |
| M9 | **Coordination of Dispatch Instructions** | Coordination of bulk system and distribution dispatch instructions to ensure optimal use of DERAs including real-time adjustments based on system conditions. |
| M10 | **Market Conflict Identification** | If one asset is participating in two markets (and is operating within the defined market rules), and there is a conflict, users are alerted to it. |
| M11 | **Reporting on DER Bidding, Dispatch, Changes, and Performance** | Provide transparency on dispatch instructutions, changes to dispatch, and performance. |
| M12 | **Market Monitoring** | Enable continuous observation of wholesale and distribution market activities to enable identification of regulatory issues, market faults, and security issues via analytics processes. |

### *Operational Coordination*

The growth of DERs and the utilization of DER services increase the complexity for bulk systems and distribution operators. This necessitates a robust operational coordination framework, effective communication, and sufficient visibility to ensure safe, reliable operation and management of both wholesale and distribution networks. This requires that TSOs, DSOs, and Aggregators work together to monitor and manage power system reliability. These capabilities require robust and scalable communication channels to share information. This coordination is essential to ensure that DER operation does not lead to operational issues.

Specifically, real-time visibility into the deliverability of power and other services at the interchange points between transmission and distribution networks is foundational. Also fundamental is a shared operational network model of the transfer capability between transmission and distribution networks and the respective grid state information. The model allows for visibility into both planned and unplanned outages and derates for the bulk power system and distribution grid.

*Operational coordination among TSOs, DSOs, and Aggregators regarding grid operational status requires robust and scalable communication channels to ensure power system reliability.*

In addition, TSOs and DSOs need to share day-ahead forecasts and schedules for DER services to anticipate their impact on the distribution grid and bulk power system. This includes identifying potential distribution-level constraints, or other conflicts in the day-ahead phase that could affect either operation.

Figure 5 illustrates the interactions among Aggregators, TSOs, and DSOs to ensure both market and operational coordination. As described earlier, the high level of interactivity among these entities makes clear why standard interfaces, a standard data model, and a common platform are foundational for ensuring reliable and cost-effective coordination.

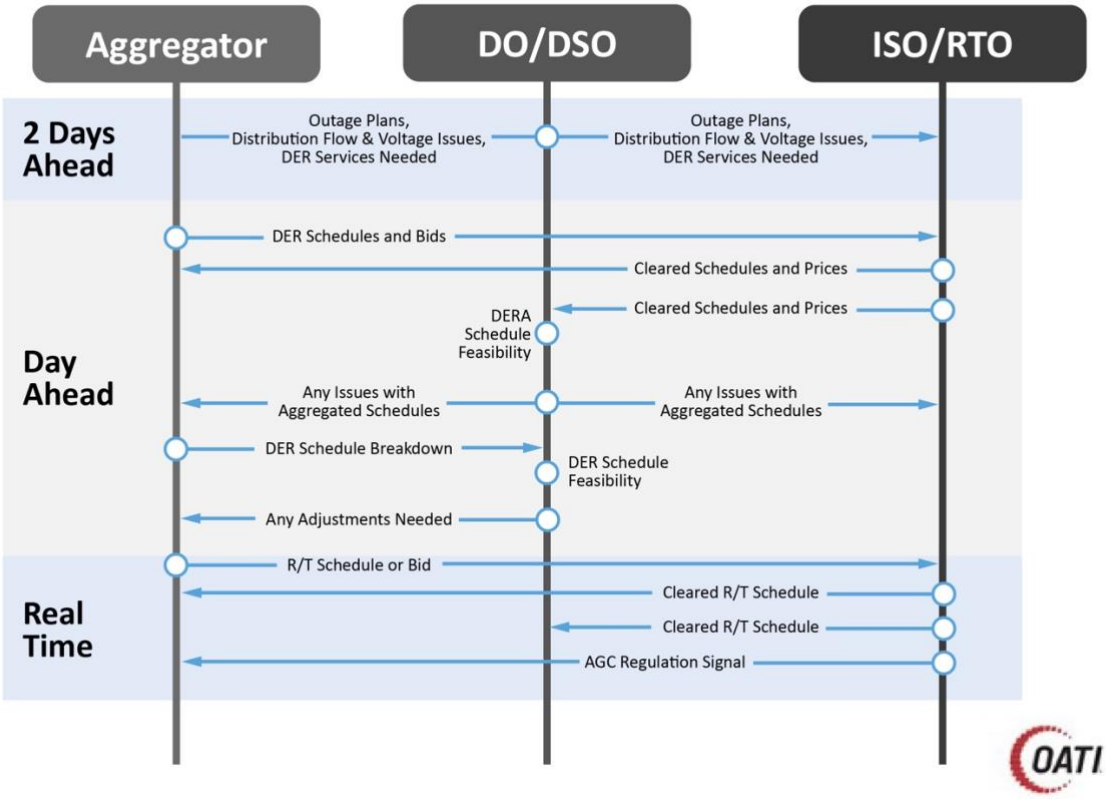


*Figure 5. Illustrative Example of Market and Operational Coordination Interaction*

Additionally, in case of emergencies or grid instabilities, TSOs and DSOs must have coordinated responses and effective information exchange to ensure power system reliability and the safety of the DER assets and the broader grid. Table 3 provides a high-level list of functionalities for TSO and DSO operational coordination as an initial set for further examination of the needed requirements.

*Table 3. High-Level Operational Coordination Functionality*

| ID | Functionality | Description |
|---|---|---|
| O1 | **Real-Time T-D Node Visibility** | Visibility into the Transmission-Distribution (T-D) interface with real-time data on node performance, energy flows, and potential constraints. |
| O2 | **DER Reliability Monitoring** | DER compliance with technical standards for interconnection and performance to ensure reliability and safety of the grid. |
| O3 | **Distribution Grid State Information** | Real-time Operational information on specific distribution grid outages, curtailments, and other changes to deliverability, including affected locations and expected duration. |
| O4 | **T&D Deliverability Optimization** | Capability to enable optimizing demand and supply (e.g., constraints) across transmission and distribution. |
| O5 | **Operational Instructions Record** | Real-time operational log of actions involving changes in deliverability of DER services due to changes in grid conditions (e.g., outages, line derates, circuit switching, etc.). |

### *Cross-Cutting Requirements*

There are several important cross-cutting requirements for market and operational coordination. They serve as the criteria for the operation and performance of a system, rather than specific functions as described above. Cross-cutting requirements, referred to as *non-functional requirements* in technology development, include the following:

**Performance** is the responsiveness of the system to execute any given operation and information exchange within defined aspects, including throughput, latency, or transaction time. This means being able to support, for example, 5-minute wholesale market operations and shorter information response times for the reliable operation of physical transmission and distribution systems.

**Usability** ensures that market participation and coordination are transparent and accessible to all qualified Aggregators and other grid service providers to achieve quantified objectives with effectiveness, efficiency, and satisfaction.

**Interoperability** ensures that the systems and protocols used by TSOs, DSOs, and Aggregators are standards-based and interoperable, facilitating seamless communication and operational coordination. Standard interfaces streamline processes by reducing the need for custom integration work. This efficiency is crucial for real-time operations where speed and reliability are paramount.

**Scalability** is the ability of the system to handle the growth of DER participation to the levels envisioned, such as an increase in data volume, the number of users, or the number of transactions without compromising performance. It requires a flexible and scalable system that can accommodate evolving market conditions (e.g., rules and structures) and technological and business model advancements.

**Data Integrity** ensures that data are accurate, consistent, and safeguarded from unauthorized modifications. Data needed for market participation (i.e., asset and product definition data) should be available in a standard form, underpinned by a consistent taxonomy of asset and product features and attributes. This ensures that the data exchanged among various sources are consistent and comparable.

**Robust Communication Channels** are established among TSOs and the associated DSOs and Aggregators for the exchange of DER and market data and operational and performance information. Facilitating effective coordination requires telemetry from DERs and Aggregators, as applicable, as well as from DSOs for distribution system deliverability conditions.

**Security and Privacy** involve applying the appropriate standards to provide for the secure handling of data related to DER operations, market participation, and settlements and protecting the rights of individuals and the confidentiality of their data.

**Compliance and Reporting** involves complying with laws, regulations (including FERC Order No. 2222 and state regulations), standards, and guidelines relevant to the electricity system and reporting on DER performance, dual market activity, and operational data. It also includes maintaining detailed records and the reporting of coordination efforts, decisions, and outcomes for regulatory oversight.

Table 4 provides a list of cross-cutting requirements for a MOC platform as a starting point for further consideration.

*Table 4. Cross-Cutting Requirements for a Market and Operational Coordination Platform*

| ID | Functionality | Description |
|---|---|---|
| N1 | **Standard Data Model** | Standard data model that underpins asset, product, and market participant definitions that are used to categorize, describe, and harmonize them across multiple markets, thereby helping participants to find each other and comparing products and assets. |
| N2 | **User Registration** | Registration of users onto the exchange facilitating access to multiple markets through a unified experience. |
| N3 | **Role-Based Access Control System** | Enable management of user read/write privileges (e.g., Aggregators, DSOs, TSOs, regulators) with secure access protocols. |
| N4 | **Transaction Logging and Historical Data Archiving** | Maintain record of all data on prices, volumes, dispatch, trades, metering, and settlement as well as interactions and changes within the registry for audit and analysis. |
| N5 | **Data Management** | Provide efficient, standardized management of data related to DER performance, market transactions, operational activity, and compliance. |
| N6 | **Reporting** | Provide user-defined reports on DER participation and performance, market and operational activity, and related compliance information. |
| N7 | **Transparency and Accessibility** | Ensure that market participation is transparent and accessible to all qualified DERs and aggregators, without undue barriers. |
| N8 | **System of Systems Interoperability** | Interoperability with DER Aggregator, TSO, and DSO systems through implementation of secure application programming interfaces, using open standard protocols to facilitate seamless communication and operational coordination. |
| N9 | **Telemetry Interfaces** | Enable interfaces with required telemetry, which can be at the individual DER or DER aggregation level. The level of telemetry required may depend on the nature of the DER's participation in the wholesale market and market rules. |
| N10 | **Secure and Reliable Communication Channels** | Enable robust communication channels for the exchange of operational data, market signals, and dispatch instructions. |
| N11 | **Business Process and Approval Functions** | System enables the process mechanisms to ensure implementation of markets and operational processes, and related approval processes. |
| N12 | **Security and Privacy Protections** | System enables compliance with security and privacy standards for market and operational data and DER registry information. |
| N13 | **Flexibility and Scalability** | System can accommodate millions of DERs involving a wide range of technologies and aggregation compositions, and adapting to evolving market conditions and technological advancements. |

## Market and Operational Coordination Platform

A shared MOC platform enables effective communication, data exchange, and decision-making among the TSOs, DSOs, and Aggregators to support a more reliable, flexible, and sustainable energy system. The functionality discussed above may be implemented through one or more technology solutions, collectively referred to in this paper as a *platform*. Among the benefits of a shared MOC platform are the following:

- Lowers barriers to DER participation.
- Reduces transaction costs for TSOs, DSOs, and Aggregators to the benefit of ratepayers.
- Provides greater visibility into the operational conditions of DERs and distribution systems.
- Facilitates efficient and timely information exchange among many potential entities.
- Provides an activity record to support market monitoring and regulatory compliance.

The MOC platform should be technology neutral and recognize that the required functionality may be provided in one or more platform solutions, as currently commercially available (e.g., Collaborative Utility Solutions, OATI, NODES, and Recurve) or being developed by states and TSOs, such as New York[22] and PJM.[23]

*The scope and scale capabilities of a MOC platform should, at a minimum, be able to support statewide implementation for multiple distribution utilities to interface seamlessly with a TSO.*

The scope and scale capabilities of a MOC platform should, at a minimum, be able to support statewide implementation for multiple distribution utilities to interface seamlessly with a TSO. Such implementation should allow for a distinct, private, and secure environment for each DSO while enabling common interfaces and features for all DSOs. Also, a MOC platform should avoid the duplication of functions and make use of existing systems operated by the TSO, DSO, Aggregator, state agency, or other entity, where they perform adequately. Examples are state DER registries, centralized and utility meter data repositories, market and dispatch systems, distribution operational systems (e.g., Advanced Distribution Management System [ADMS] and/or Supervisory Control and Data Acquisition [SCADA], settlement and payment systems). This reduces the complexity and risk of an unmanageable network of proprietary interfaces that may otherwise proliferate. Such a common MOC platform simplifies the implementation and operation of processes and reduces related costs.

[22] For example, New York implemented a DER Integrated Data System. https://der.nyserda.ny.gov/

[23] PJM intends to implement a central hub for coordination and communication among PJM, the DER Aggregator, and the applicable distribution utility. https://www.pjm.com/-/media/documents/ferc/filings/2023/20230331-er22-962-001.ashx

## MOC Platform Architecture

Figure 6 illustrates a conceptual architecture for a market and operational coordination platform that is consistent with the capabilities and functionality described above.

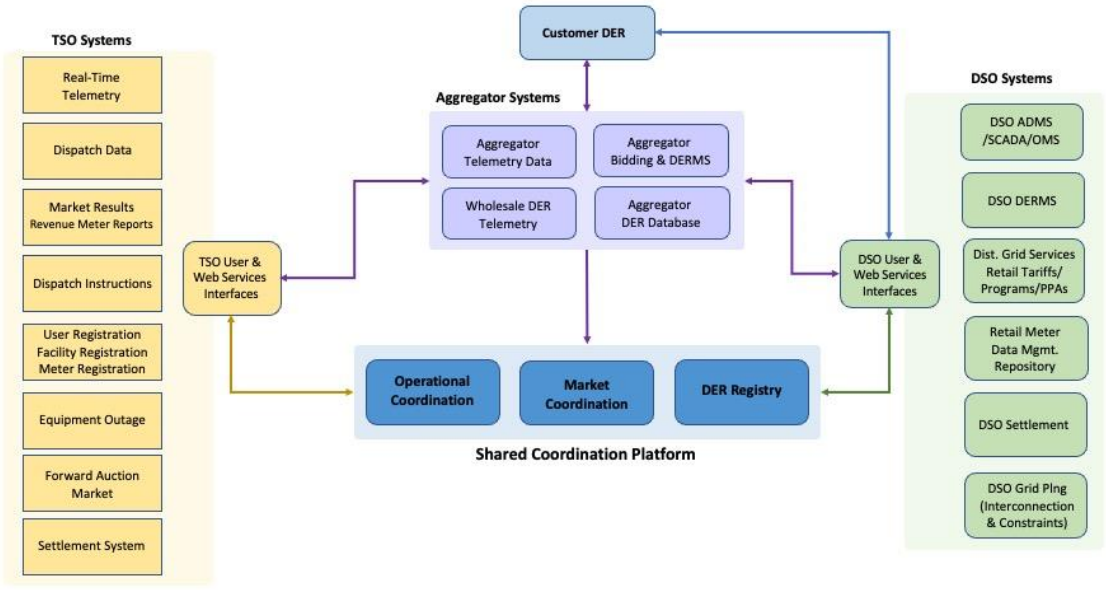


*Figure 6. Conceptual MOC Platform and Interfacing Operational Systems*

This conceptual diagram outlines the various systems and simplified view of the information interfaces required for the operation, market coordination, and settlement of DERs among Aggregators, TSOs, and DSOs. This diagram does not reflect all system components and internal interfaces among the various operational systems. A coordination platform would be detailed in a more complete system architecture as part of a system development and implementation effort. Appendix B provides a more complete illustration of the DSO systems that may be involved to enable the use of DER services and manage grid operations. The following tables provide summary descriptions of the identified system components for each entity (color-coded) in Figure 6.

*Table 5. TSO System Components*

| TSO Systems | Description |
|---|---|
| **Real-Time Telemetry** | Data streams from DERs and the distribution utility using a standard communications protocol, including information about the current operational status of energy resources and deliverability at the transmission-distribution interchange. |
| **Dispatch Data** | Instructions and data are sent to energy resources regarding how much power to produce or consume. |
| **Market Results and Revenue Meter Reports** | Information about market operations and financial transactions/results related to energy production and consumption. |
| **Dispatch Instructions** | Specific commands from the TSO to DERs concerning the dispatch of services. |
| **User, Facility, and Meter Registration** | Processes for registering users, energy facilities, and meters in the TSO system. |
| **Equipment Outage** | Reporting and management of equipment outages within a TSO's purview. |
| **Forward Auction Market** | A platform for capacity and ancillary services market transactions. |
| **Settlement System** | Financial reconciliation of market operations, including payments to and from market participants. |
| **TSO User Interface** | The interface through which users interact with the TSO systems. |
| **Web Services Interface** | Communication gateway using application programming interfaces for data exchange with external systems. |

*Table 6. Coordination Platform Components*

| Coordination Platform | Description |
|---|---|
| **DER Registry** | A common, secure database and management system for registering individual DERs and aggregations, including the requisite standardized information to participate in the wholesale market and/or distribution services and support reliable operations. |
| **Market Coordination** | A rules-based system to automate the implementation of wholesale market and retail rules. The system manages coordination between TSO and DSO day-ahead DER services bids and schedules, schedule validations, and real-time changes to DER aggregations, including unplanned outages, curtailments, and derates. Includes behind-the-meter DER performance assessment to support TSO and DSO settlement processes. |
| **Operational Coordination** | A system to provide situational awareness at the transmission-distribution interchange and communicate changes regarding planned and unplanned outages and derates of distribution deliverability. |

*Table 7. DSO System Components*

| DSO Systems | Description |
|---|---|
| **ADMS/SCADA/OMS** | The Advanced Distribution Management System (ADMS) and/or Supervisory Control and Data Acquisition (SCADA) and Outage Management System (OMS) are used for the network model, monitoring and controlling the distribution grid, and identifying and capturing distribution outage information. |
| **DERMS** | A Distributed Energy Resource Management System (DERMS) is used by the distribution utility to dispatch individual DERs (e.g., under a flexible load program) and send dispatch instructions to Aggregators (for DER aggregations) for distribution services. |
| **Distribution Grid Services** | The management of distribution grid services, such as capacity deferral/avoidance, voltage regulation/reactive power, and resilience, including the contractual and financial aspects, such as tariffs, programs, and contracted services. |
| **Distribution Grid Planning (Interconnection and Deliverability)** | The planning and management of grid interconnections and operational engineering to ensure the deliverability of energy. |
| **Retail Meter Data Management and Repository** | Utility meter data collection and data management system, including any separate metering of behind-the-meter DERs. |
| **Retail Settlement/Billing** | Management of the financial reconciliation of retail DER services transactions under tariffs, programs, and contracts. |

*Table 8. DER Aggregator System Components*

| Aggregator Systems | Description |
|---|---|
| **Aggregator and DER Telemetry** | TSO and DSO required telemetry interfaces to the Aggregator that provide the net response of the aggregated portfolio. The Aggregator has monitoring, measurement, and communications capability at each DER in an aggregation to manage its portfolio. |
| **Wholesale DER Telemetry** | Larger DERs may have TSO-required metering and communications as used for large-scale generation. |
| **DER Database** | Database of individual DERs in the Aggregator's portfolio, such as relevant information regarding asset information and performance characteristics. This type of information also is required for the DER registry. |
| **Bidding and DERMS** | Aggregator systems to manage bidding, scheduling, and settlement. Also, DERMS to directly dispatch aggregated DERs in response to TSO or DSO dispatch instructions and signals. |

## Grid Architectural Considerations

Dual participation of DER Aggregators providing services for wholesale electricity markets and distribution grids creates a hybrid structure that can create operational conflicts and reliability risks if not properly addressed. Grid Architecture[24] highlights several critical considerations for a coordination framework for DER integration, emphasizing the need for clear visibility, optimized layer interaction, scalability, and cybersecurity, while cautioning against bypassing hierarchical operating tiers, information gaps, conflicting control signals, and excessive data latencies.

*Dual participation of DER Aggregators providing services for wholesale electricity markets and distribution grids creates a hybrid structure that can create operational conflicts and reliability risks if not properly addressed.*

*Table 9. Architectural Considerations for Market and Operational Coordination*

| | Considerations | Description |
|---|---|---|
| Desirable | **Observability** | Function related to operational visibility of the distribution network and integrated DER. Observability needs of DSO and TSO depend on how the coordination framework is specified. |
| Desirable | **Layered Optimization** | Large-scale optimization problems are decomposed into multiple sub-problems at discrete layers of the electric system within a coordinated structure. |
| Desirable | **Scalability** | Ability of system's processes and technology design to work well for very large quantities of DER resources. Coordination architecture can enhance or detract from this desired capability. |
| Desirable | **Cybersecurity Vulnerability** | Reduce cyber vulnerability through architectural structure. Structure can expose grid systems to more or less vulnerability depending on data flow structure, which depends on coordination framework. |
| Avoid | **Tier Bypassing** | Creation of information flow or instruction/dispatch/control paths that skip around a tier of the power system hierarchy, thus opening the possibility for creating operational problems. To be avoided. |
| Avoid | **Coordination Gapping** | Nonexistent information exchange between entities that need to coordinate respective market, operations, and settlement functions. To be avoided. |
| Avoid | **Hidden Coupling** | Two or more controls with partial views of grid state operating separately according to individual goals and constraints; such as simultaneous but conflicting signals to DER from customer, DSO, and TSO. To be avoided. |
| Avoid | **Latency Cascading** | Creation of potentially excessive latencies in information flows due to the cascading of systems and organization through which the data must flow serially. To be avoided. |

Source: J. Taft, Pacific Northwest National Laboratory

[24] Pacific Northwest National Laboratory, Grid Architecture. https://gridarchitecture.pnnl.gov/

The proposed MOC platform addresses these critical architectural considerations, ensuring the effective coordination of market participation and operational activities of DER aggregations. Specifically, the MOC platform addresses each of these architectural principles as follows:

- **Observability.** The platform provides comprehensive visibility into the status of individual DERs and DER aggregations, including their eligibility, operational state (such as available, out-of-service, or curtailment/derate), market participation, and transactions. It also offers information on the operational state of the grid, including outages and derations due to switching, as well as performance data for individual DERs and DER aggregations. Governance ensures the appropriate sharing of data across stakeholders while maintaining privacy.
- **Layered Optimization.** The platform allows TSOs, DSOs, and DER providers to optimize the usage of DERs for their individual needs with mechanisms to resolve potential conflicts in dispatch or utilization.
- **Scalability.** The platform is conceived to support current and future demands for market and operational coordination without scale limitations.
- **Cybersecurity Vulnerability.** By reducing the number of point-to-point interfaces among the TSOs, DSOs, and Aggregators, the platform minimizes the cybersecurity threat plane and other vulnerabilities, such as those related to communication and data transmission reliability.
- **Tier Bypassing.** The platform provides a transparent and coordinated structure that facilitates dual participation in both wholesale and distribution grid services, as well as customers' personal use of their DERs, resolving issues that could arise from bypassing certain tiers in the system.
- **Coordination Gapping.** The platform addresses potential gaps in the lifecycle of DER aggregation participation, from registration to settlement.
- **Hidden Coupling.** The platform reduces the risk of conflicting dispatch instructions to DERs from the TSO and DSO by effectively implementing structural rules and processes designed to prevent them.
- **Latency Cascading.** Central data repositories on the platform help to avoid latency issues and the operational risks associated with multiple datasets and pathways. Dispatch instructions are communicated efficiently from the TSO or DSO directly to Aggregators, maintaining effective communication practices and supporting the latency requirements of both the TSO and DSO.

## Conclusion

The wide-scale use of DER services for both distribution needs and wholesale markets necessitates an effective coordination framework among TSOs (including RTOs/ISOs), DSOs, and Aggregators, and transparency to RERRAs. Such a framework will involve several processes and related business requirements. These requirements will need to be implemented through enabling information and software system(s). A shared MOC platform would accomplish the following:

- Reduce barriers to DER participation by facilitating efficient integration into electricity markets and aligning with FERC Order No. 2222.
- Reduce transaction costs for TSOs, DSOs, and Aggregators to the benefit of ratepayers.
- Enhance operational reliability and efficiency by streamlining coordination and information

exchange among TSOs, DSOs, and Aggregators, thus avoiding the complexity, risks, and costs of ad hoc implementation of disparate systems.

- Enable the expanded use of DER services as the number and diversity of DERs increase and the need for system flexibility grows.
- Ensure adherence to regulatory requirements, enabling the efficient and equitable participation of DER aggregations in wholesale markets and providing distribution services.

This paper is intended to stimulate discussion among policymakers, regulators, and stakeholders to guide the consideration of a shared MOC platform. A proactive approach from the RERRA will be essential to realize the full benefit of the DER services for both wholesale and distribution grid services. The RERRA plays a key role in ensuring that the most efficient coordination solutions are developed to minimize ratepayer costs and avoid stranded costs from initial solutions that cannot meet a state's policy objectives. Therefore, RERRA leadership is needed to define the objectives and considerations for the development of a shared MOC platform.

*The RERRA plays a key role in ensuring that the most efficient coordination solutions are developed to minimize ratepayer costs and avoid stranded costs from initial solutions that cannot meet a state's policy objectives.*

The importance of collaborative decision-making emphasizes the need to involve various stakeholders in the development of a market and operational coordination solution. Organizing workshops and advisory panels with stakeholders will help translate the state/region-specific goals, along with FERC Order No. 2222 compliance plans, into actionable distribution utility plans.

The description of the coordination functionalities required underscores the need for substantial investment and technical competence. The high-level platform requirements discussed here are a starting point; however, they are not exhaustive. Evaluation and development of such a platform will necessarily start with the identification of detailed functional and technical requirements based on the specific needs of each TSO and RERRA jurisdiction. There also is a need to determine a lead development organization, implementation and ongoing funding, and a governance structure for a shared MOC platform. Furthermore, stakeholders should anticipate and plan for future platform adaptations. As the energy sector evolves, so will the requirements and functionalities of the platform. This type of holistic effort will support the development of a robust and scalable MOC platform, including decisions on technology solutions, implementation plans, and costs.

# Appendix A: FERC Order No. 2222 to Functional Requirements Map

The following table maps FERC Order No. 2222 requirements[25] to the high-level DER Registration, Market, Operational, and Cross-Cutting functionalities identified in Tables 1, 2, 3, and 4, respectively, in this paper.

| Order No. 2222 Section | Number | FERC Determination | Functionality Requirement ID |
|---|---|---|---|
| **Eligibility to Participate in RTO/ISO Markets Through a DER Aggregator** | 130 | Require each RTO/ISO to (1) establish DER Aggregators as a type of market participant, and (2) allow Aggregators to register DER aggregations under one or more participation models in the RTO's/ISO's tariff that accommodate the physical and operational characteristics of the DER aggregation. | R1–R7 |
| **Double Counting of Services** | 159 | Allow RTOs/ISOs to limit the participation of resources in RTO/ISO markets through a DER Aggregator that is receiving compensation for the same services as part of another wholesale or retail program. | R1, R3–R7 |
| | 160 | Require each RTO/ISO to revise its tariff to (1) allow DERs that participate in one or more retail programs to participate in its wholesale markets; (2) allow DERs to provide multiple wholesale services; and (3) include any appropriate restrictions on the DERs' participation in RTO/ISO markets through DER aggregations, if narrowly designed, to avoid counting more than once the services provided by DERs in RTO/ISO markets. | R1–R7 |
| **Information and Data Requirements** | 236 | Require each RTO/ISO to revise its tariff to (1) include any requirements for DER Aggregators that establish the information and data that a DER Aggregator must provide about the physical and operational characteristics of its aggregation; (2) require DER Aggregators to provide a list of the individual resources in its aggregation; and (3) establish any necessary information that must be submitted for the individual DERs. FERC also requires each RTO/ISO to revise its tariff to require DER | R1–R7; M1, M7, M8; O2; N2–N7, N10, N11 |

[25] DOE FERC, Docket No. RM18-9-000; Order No. 2222, Issued September 17, 2020. https://www.ferc.gov/sites/default/files/2020-09/E-1_0.pdf

| | | | |
|---|---|---|---|
| | | Aggregators to provide aggregate settlement data for the DER aggregation and to retain performance data for individual DERs in a DER aggregation for auditing purposes. | |
| | 238 | Require each RTO/ISO to revise its tariff to require DER Aggregators to provide a list of the individual DERs participating in their aggregations to the RTO/ISO. Each RTO/ISO also must require that the DER Aggregator update the list of individual resources and associated information as it changes. | R1–R5; M1, M11; N2 |
| | 240 | Require each RTO/ISO to revise its tariff to require each DER Aggregator to maintain and submit aggregate settlement data for the DER aggregation so that the RTO/ISO can regularly settle with the DER Aggregator for its market participation and to provide, upon request from the RTO/ISO, performance data for individual resources in a DER aggregation for auditing purposes. | M6, M10, M11, M12; N4–N7 |
| **Metering and Telemetry Requirements** | 269 | Require that metering requirements proposed by RTOs/ISOs should rely on meter data obtained through compliance with the metering system requirements of the distribution utility or local regulatory authority, whenever possible, for settlement and auditing purposes. | M7, M8; O1–O5; N5, N6, N8–N10, N12 |
| | 270 | Require that RTOs/ISOs coordinate with distribution utilities and RERRAs to establish protocols for sharing metering and telemetry data and that such protocols minimize the cost and other burdens and address concerns with privacy and cybersecurity. | M7, M8; O1–O5; N5, N6, N8–N10, N12 |
| **Market Rules on Coordination** | 278 | Require each RTO/ISO to revise its tariff to establish market rules that address coordination among the RTO/ISO, the DER Aggregator, the distribution utility, and the RERRA. | R1–R7; M1–M12; N6, N7, N10–N13 |
| | 292 | Require each RTO/ISO to modify its tariff to incorporate a comprehensive and non-discriminatory process for timely review by a distribution utility of the individual DERs that comprise a DER aggregation. The review is | R1–R7; M1–M4; N2 |

| | | | |
|---|---|---|---|
| | | triggered by initial registration of the DER aggregation or incremental changes to a DER aggregation already participating in the market. Each RTO/ISO must coordinate with distribution utilities to develop a distribution utility review process that includes criteria by which the distribution utilities determine whether (1) each proposed DER is capable of participation in a DER aggregation, and (2) participation of each proposed DER in a DER aggregation will not pose significant risks to the reliable and safe operation of the distribution system. To support this review process, RTOs/ISOs must share with distribution utilities any necessary information and data collected about the individual DERs participating in a DER aggregation. In addition, the results of a distribution utility's review must be incorporated into the DER aggregation registration process. | |
| | 296 | Require each RTO/ISO to revise its tariff to include, as part of its distribution utility review processes, the criteria by which distribution utilities can determine that a DER (1) can participate in an aggregation (e.g., the DER is not already participating in a retail DER program in which the RERRA conditioned the resource's participation on not participating in RTO/ISO markets), and (2) does not pose significant risks to the reliable and safe operation of the distribution system. | R1–R7; M1–M4; N2, N8 |
| | 299 | Require each RTO/ISO to incorporate dispute resolution provisions as part of its proposed distribution utility review process. | M9–M12 |
| **Ongoing Operational Coordination** | 310 | Require each RTO/ISO to revise its tariff to (1) establish a process for ongoing coordination, including operational coordination, that addresses data flows and communication among itself, the DER Aggregator, and the distribution utility; and (2) require the DER Aggregator to report to the RTO/ISO any changes to its offered quantity and related distribution factors that result from distribution line faults or outages. FERC also requires each RTO/ISO to revise its | M5–M9, M12; O1–O5; N8–N11 |

| | | | |
|---|---|---|---|
| | | tariff to include coordination protocols and processes for the operating day that allow distribution utilities to override RTO/ISO dispatch of a DER aggregation under circumstances where such an override is needed to maintain the reliable and safe operation of the distribution system. | |
| **Role of the Relevant Electric Retail Regulatory Authorities (RERRAs)** | 322 | Require each RTO/ISO to specify in its tariff, as part of the market rules on coordination among the RTO/ISO, the DER Aggregator, and the distribution utility, how each RTO/ISO will accommodate and incorporate voluntary RERRA involvement in coordinating the participation of aggregated DERs in RTO/ISO markets. | R1–R7; M1, M3, M4, M10–M12; N3, N6, N7, N12 |
| **Modification to List of Resources in Aggregation** | 336 | Require each RTO/ISO to revise its tariff to specify that DER Aggregators must update their lists of DERs in each aggregation (i.e., reflect additions and subtractions from the list) and any associated information and data. DER Aggregators will not be required to reregister or requalify the entire DER aggregation. Any modification triggers the distribution utility review process. | R1–R7; M1, M3, M4 |
| | 338 | Require each RTO/ISO to ensure that DER Aggregators must update such information if any modification to the list of resources participating in the aggregation results in a change to the aggregation's performance. | R1–R7; M1, M3, M4 |
| **Market Participation Agreement** | 352 | Require each RTO/ISO to include a standard market participation agreement that defines the DER Aggregator's role and responsibilities and its relationship with the RTO/ISO and an Aggregator to execute the agreement before it can participate in RTO/ISO markets. The market participation agreement must include an attestation that the DER aggregation is compliant with the tariffs and operating procedures of the distribution utilities and the rules and regulations of any RERRA. | M1–M12 |

## Appendix B: Illustration of DSO Operational and Information Systems

The EnerNex figure below provides a more complete illustration of the various DSO operational and information systems involved with operating a distribution grid and orchestrating DER services.