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Distribution System Operator Interactions with Transmission System Operator

Distribution Operations and Planning

Abstract

Because the actions of one impact the other, the transmission system operator (TSO) and the distribution system operator (DSO) have always had an open line of communication. Although the technology to operate the system has evolved, the roles and responsibilities have been honed through years of familiarity. However, the rapid adoption of many small distributed energy resources (DER) sited on both transmission and distribution systems is changing the functions that each must execute to maintain the reliability and stability of the combined electrical system. This paper provides insights into the role of the distribution organization and the DSO when distribution-connected generation begins to be relied upon to provide both generation and ancillary services to the transmission grid.

Keywords

Distributed energy resources (DER)
Flexible interconnection agreements
T&D planning
Transmission-sited DER

Introduction

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Connecting Distributed Energy Resources to the Distribution System

Because the distribution system was initially built to deliver power from substations to the customer, the addition of DER can create events in which the operating limits of the distribution system are exceeded. To identify the potential issues associated with a DER installation, utilities perform an engineering analysis of the impact of the proposed DER on the system. If the analysis determines that operational limits will be exceeded, the DER developers typically have three options to mitigate the excursions: reduce the size of the DER, change the interconnection location of the DER, or bear additional costs and delays associated with distribution system upgrades before the DER can be connected. Each of these mitigation techniques has potential negative financial impacts to the DER developer.

The potential for the DER to create negative operating conditions depends on several time-varying variables. A detailed review of the variables may identify only a few hours per day or year that the operation of the DER must be altered to eliminate operating violations. Some utilities are working with the DER developers to execute flexible connection agreements. The flexible connection agreement allows the utility to control, either directly or indirectly, the watts and/or reactive power generated or absorbed by the DER to mitigate any operating violations. The time periods during which the DER must operate with a distribution constraint may be relatively small compared to the time associated with unrestricted generation. For areas in which utilities are actively seeking an increase in DER, flexible interconnection agreements have proven to increase the installation of distributed resources. Once DER become a manageable asset whose output can be adjusted based on grid conditions, the distribution system supports more average energy transfer and more DER connected in more locations.

Utility-specific examples of connection agreements are discussed in detail in the EPRI 2018 report 3002012964, *Flexible Interconnection for Distributed Energy Resources*.

Auxiliary Benefits of Distributed Energy Resources

As DER become more prevalent, they can begin to supply ancillary benefits to the entire grid. These benefits may come in the form of frequency regulation, Volt/VAR control, or serving as "spinning" reserves. The extent to which the DER can provide these benefits depends on the DSO's ability to accurately monitor the DER, control the DER, and communicate the data associated with the operation of the DER in a manner that can be used by the TSO. For the TSO to be able to properly model the benefit of the DER, the DSO will need to aggregate DER on its feeders at strategic interconnections with the transmission system. The DSO will also need to communicate any real-time changes to the connection point for the DER. For example, prior to moving a DER from one substation source to an alternative source, the impact of the change to the transmission system must be understood and communicated. Understanding this impact requires that the DSO know and communicate which transmission service point is serving the portion of the grid to which the DER are connected. Planned distribution switching that changes the transmission source of a distributed energy resource will require the distribution operator to coordinate with the transmission modeling group before the planned switching is executed.

Historically, the TSO has requested that the DSO provide reactive power support. Capacitor banks installed on the distribution system were close to the load and smaller than capacitor banks installed at transmission connection points (in substations). This made the installations more effective and less costly to maintain. The connection of transmission-sited DER has changed this paradigm. Remote siting of generation on the transmission system may prompt the TSO to request the distribution system to absorb reactive power to lower the voltage impact of the DER. Open and clear communication between the TSO and DSO will be necessary to operate the electrical system within the operating limits, and the request to produce or absorb reactive power may change multiple times within a day and be very connection-point-specific. DSOs with the ability to change the operation of capacitors and smart inverters to dynamically meet the needs of transmission may increase the hosting capacity of the transmission system.

As an aggregate of DER becomes a substantial portion of the generation mix, the availability of the DER must be known and constantly evaluated. If some portion of the DER's output is flexible and being limited, the dispatch schedule must be communicated and agreed upon between the DSO and the DER owner—and aggregated to the proper transmission connection point. This will require a prior agreement on the availability and connection point of energy storage devices if they are being counted on to provide ancillary service benefits.

Planning Practices

In the current environment, the planning departments of distribution and transmission share data from each system to drive the overall results. With the proliferation of DER, the amount of data exchange will be multiplied. Taking the example of the scenario planning and network planning time frames, the data or decision dependency interactions between functions—both internally within transmission and distribution utilities and between transmission and distribution—are mapped in Figure 1.

The figure shows a typical present-day scenario (top) and a future scenario (bottom) in which increased coordination is required to manage a decentralized system. In this figure, interactions across the transmission and distribution interface are colored. The magnitude of the shift between current practices and future coordination schemes is illustrated by the addition of the new colored links between distribution and transmission utilities. The green colored lines indicate that the direction of the data exchange is from distribution to transmission, whereas the purple links indicate a data exchange from transmission to distribution.

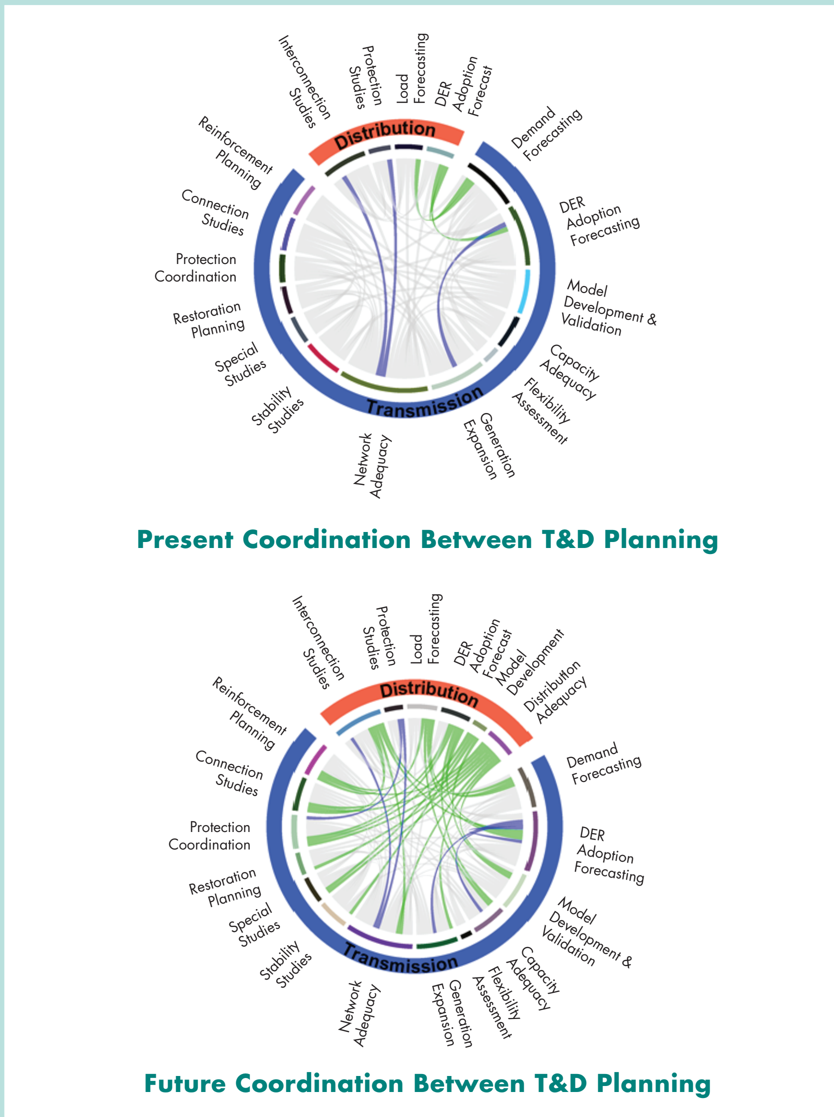

Figure 1. Typical present-day scenario (top) and future scenario (bottom) in which increased coordination is required to manage a decentralized system

Operational Control

Anuta, J., "Probing Question: What Heats the Earth's Core." Building from the planning time frame in which data exchange is becoming increasingly important, control over DER is an important consideration in the operational time frame. In the planning time frame, stakeholders typically make decisions associated with investments in assets or processes on their own grid. However, in the operational time frame, DER may follow a dispatch signal set by the bulk system (either directly or indirectly using a hierarchical control architecture) or by the distribution utility—or based on the asset owner's own use preferences (for example, self-consumption resulting from net metering). Each of these choices implies differing requirements for observability and control, with differing degrees of potentially induced consequences for each stakeholder.

There is a large discrepancy in the amount of interaction and involvement of the distribution organization based on the connection agreements of the DER. DER installations that have fixed connection agreements and have been sited to operate at maximum capacity without causing distribution power quality issues are much different from those operating through flexible agreements that must be monitored and controlled to meet both generation and power quality requirements. DER installations in the United States that have been deployed under fixed agreements without consideration of auxiliary benefits have the dispatch of the DER at the sole discretion of the DER owner, with distribution utilities potentially having monitoring capability (see Figure 2).

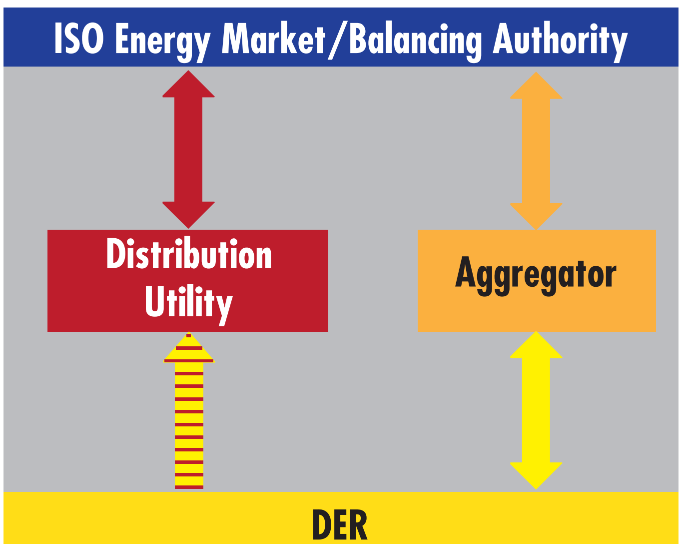

Figure 2. Geothermal power plants tap heat that originates from deep inside the Earth. (Credit: Lawrence Livermore National Laboratory)

Under flexible interconnection agreements, distribution will directly monitor all DER connections and send control signals directly to the DER or indirectly through a DER aggregator (see Figure 3). Distribution commands will be connection-location-specific. Distribution will also be required to work with DER owners and aggregators to develop schedules that mitigate operating violations on either the distribution or transmission system. The schedules developed will be the basis for any reimbursement of auxiliary benefits to the T&D grid.

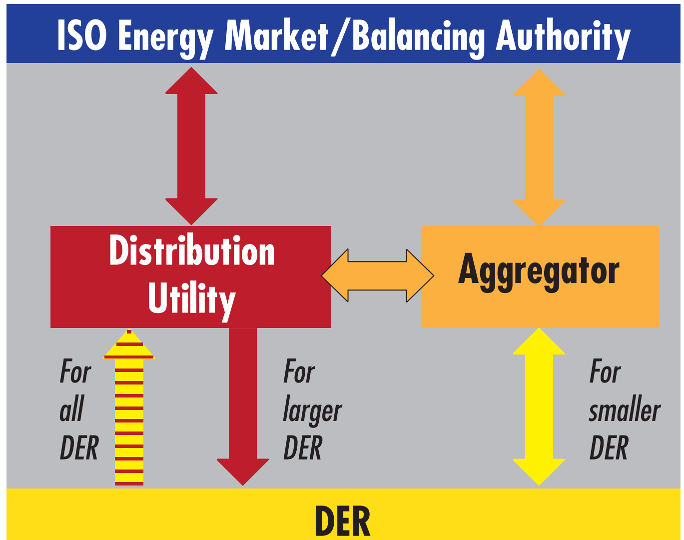

Figure 3. Interconnections for flexible (non-firm) DER agreements

Data Sharing Mechanisms

International standards have been under development to facilitate data sharing mechanisms between individual DER devices and DER management systems (DERMS) as well as between distribution/energy management systems and DERMS. The latter may enable data sharing between the transmission and distribution level operational functions. IEC standard 61968 specifies the common information model (CIM) for distribution applications; IEC 61968-5, which is currently under development, may specify interfaces for operational planning and optimization. EPRI contributed to the IEC 61968-5 DER group management functional specifications developed between 2013 and 2017.

Examples of DER group management functions include group creation, maintenance, and deletion as well as basic functions such as capability discovery, status monitoring, and historical aggregate meter data. For energy-related interactions, functions such as maximum real power limiting, real power dispatch, and ramp rate limit control may become available. Voltage-related interactions may use functions such as reactive power dispatch and voltage regulation function. DER group management functions are suitable for both serial and parallel architectures and any combination thereof. This is in line with federated architectures for DER management and control. Additional details can be found in EPRI report 3002014321, *Managing Integrated Distributed Energy Resources Programs Communications, Cyber Security, and Architecture*. Going forward, mapping of the transmission functions and the DER group management functions will help identify potential gaps and allow for functional alignment in current international standard development.

Conclusions

Power systems are evolving as the desire for increased DER penetration encourages companies and developers to accept flexible interconnection agreements. The increased penetration will create opportunities for DER to provide auxiliary benefits to system stability. Both transmission and distribution systems will be tasked with planning, monitoring, and controlling DER—either directly or through third parties—to ensure that the benefits are realized with no operating parameters violated. Standardization of DER group management functions and information protocols are recommended to achieve interoperability.

Distribution will be tasked with aggregating distribution-connected DER to strategic transmission connection points. Potential changes to the connection point through planned system upgrades must be coordinated with transmission planning. This includes planned connection changes with a long lead time and connections impacted by emergency reconfigurations of the distribution system. Accurate mapping and real-time metering of distribution-connected DER are recommended to prepare for exchange of those data in an aggregated way. Early adoption of new DER interconnection standards—for example, IEEE Std 1547-2018—is recommended to ensure that new DER performance and functional, communication, and interoperability capabilities are built up as soon as possible—even if they are not used until later.

Transmission and distribution owner/operators will need to understand and support DER characteristics that impact the reliability of each system. Communication between the two control authorities will continue to evolve and grow. This evolution will likely involve challenges as existing compartmentalization of the industry may need to be overcome. Adherence to CIM standards will help control systems process data associated with assets connected outside of their control boundaries.

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3002015276 September 2019

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