The Transmission-Distribution Interface

Recommendations for the
U.S. Department of Energy

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1 Introduction

Historically, the separation between the electric transmission and distribution systems was distinct. Electric generating facilities connected to the transmission system that transported needed electricity, and then to customers through the distribution system. This bright line of the transmission-distribution (T-D) interface enabled responsible entities to separately and clearly regulate, plan, and operate markets, and manage the safe, reliable operation of the electric system. Roles and responsibilities were clear.

During the last decade, the power industry has experienced a significant shift, primarily concerning the location and type of resources upon which consumers rely to satisfy their electricity needs. Significant amounts of renewable, intermittent generation are being incorporated into the transmission system, creating a need for new, flexible operating capability, and more importantly to the T-D interface—the prolific or impending integration of energy resources connected to the low-voltage distribution system.

Integration of these distributed energy resources (DERs) that include not only distributed generators, but also energy storage, electric vehicles, demand response and energy efficiency, changes the paradigm under which the industry has conducted all aspects of ensuring our electric system serves public demands. The way we define, or redefine, this interface is emerging as an important issue as the line blurs around roles and responsibilities.

The U.S. Department of Energy (DOE) can help provide guidance to decision makers as they work to define new and different technical and coordination requirements to enable the transition. To this end, the Electricity Advisory Committee (EAC) offers recommendations regarding how the DOE can help advance the characterization, integration, and coordination of the T-D interface to support utilities, policy makers, and other stakeholders to develop a holistic approach for this transition as DERs continue to grow.

2 Approach

This work product was developed following a series of interviews with grid operators and industry experts around the country and worldwide. Interviewees were selected from a list suggested by members of the EAC Power Delivery Subcommittee. Subsequently, conversations with DOE representatives provided additional insights and information that the EAC incorporated into this work product.

3 Key Findings

From the interviews, the EAC summarized several key findings related to the integration of DERs across various regions and implications to the T-D interface as follows:

1. While most interviewees recognized that the T-D interface needed to evolve related to planning, operations, and markets, there was not clear or holistic direction of how their organizations planned to address the transition. There is a tendency to move directly toward technology solutions for point concerns rather than starting with a set of overarching objectives.

2. There is no current set of guidelines or reference implementation that can help decision makers develop needed holistic strategies for transmission and distribution coordination across planning, grid operations, and market operations. None of the leading state (or international) efforts has progressed to specific integrated resource, transmission and distribution planning, or detailed design and implementation of DER coordination architectures including information flows, controls, and market design.

3. States with high DER adoption are responding to distribution-level constraints and operational concerns via interconnection standards and studies including hosting capacity analysis.

4. States and wholesale market operators that are enabling participation of DERs in wholesale markets, as well as pursuing DERs as non-wires alternatives, recognize the need to coordinate the use of DERs between distribution operations and bulk system operations and markets, and are taking steps to define this interface and coordinate their use.

5. There is general acknowledgement of the need for greater visibility into DER development and operations to ensure grid safety and reliability due to the anticipated scope of DER integration, as well as customers' desire to maximize the use of their DERs, including providing distribution and transmission grid services.

6. Many regions have concluded that the new planning and operational coordination functions required are expected to be evaluated in relation to assigning roles and responsibilities between transmission system operators (TSOs) and distribution system operators (DSOs). Also, there is an open question in several states regarding whether the utility should act as the DSO.

7. Data sharing and coordination among different actors, including the operators of transmission and distribution systems as well as local regulatory authorities, will be required; how this will be accomplished is unclear due to existing jurisdictional boundaries and obligations by the various stakeholders.

8. Utilities are promoting technology interoperability to support T-D interface coordination; however, certification and testing is lagging and customization is required for each implementation.

9. A number of interviewees noted technological deficiencies across planning and operations in their readiness to support this transition. Respondents cited that not only were specific capabilities such as comprehensive modeling tools and DER forecasting lacking, but the ability to construct a system—including secure communications around the different grid devices to execute needed capabilities—was also not readily available.

10. Concerns about grid reliability responsibility are growing, as resources supplying customer load are not under the control or jurisdiction of the entity responsible for central grid planning.

3.1 DOE Work Related to the T-D Interface

The committee applauds the body of work the DOE has contributed to grid modernization as well as to the T-D interface topic. Much of the discussion on coordination comes from the grid architecture work and the Next-Generation Distribution System Platform (DSPx) publications. The EAC believes this work provides a strong base for executing the EAC recommendations for work related to the T-D interface.

4 Recommendations

The findings above represent the experiences and opinions of those interviewed. The EAC members generally agree with these finding and urge the DOE to confirm these findings as it proceeds with addressing the T-D interface. The objective of the efforts the EAC is recommending to the DOE will result in 1) determining key considerations for T-D coordination, 2) understanding the status and direction of current and planned efforts to address T-D coordination, and 3) providing guidance to enable decision makers to formulate rational processes leading to effective T-D coordination models. The envisioned effort will address the following recommendations:

Recommendation #1: Based on work undertaken to date, the DOE should create a series of educational briefings that focus on key coordination architecture principles (e.g., laminar decomposition, tier bypassing, observability, and scalability), which form the basis for comparing and guiding T-D coordination models.

- The briefings should be documented and the architectural principles examined against a range of T-D coordination models, e.g., comparing a TSO versus a DSO having the dominant role in the control and coordination of DER.

- The DOE should also articulate the associated roles and responsibilities of major participants (e.g., TSO, DSO, CCAs, aggregators) with respect to planning, grid operations, and market operations.

- We recommend the DOE brief the EAC, as well as use its convening ability to educate policy makers and other stakeholders, on the criticality of addressing these architectural principles to ensure technology investments meet overarching objectives including the ability to scale.

Recommendation #2: The DOE should assess and report on the status and planned efforts by stakeholders, including FERC, NERC, ISO/RTOS, utilities, public utility commissions (PUCs), municipalities, co-ops, etc., to improve coordination across the T-D interface.

- This effort should define the processes of various stakeholders from a business, regulatory, and technology perspective.

- This effort should examine the impact of regional differences on coordination models.

- The reporting should provide an understanding of the trajectory of T-D coordination efforts, discuss potential issues (including jurisdictional issues), and identify gaps in institutional processes and technological capabilities, e.g., planning models.

- Through this reporting, the DOE should work with the EAC to determine its role with respect to the FERC's and states' efforts to help facilitate interaction between various state and federal jurisdictions where coordination is required.

Recommendation #3: The DOE should develop guidance by providing a process framework that can inform the development of holistic strategies for T-D coordination.

- The guidance should: 1) enable decision makers to identify required capabilities based on their objectives; 2) examine the effectiveness of various coordination options, including cost and complexity considerations; 3) apply stakeholder processes to define roles, responsibilities, and information/business requirements of all participants; 4) develop sensing, communication, and control requirements; and 5) determine the appropriate mix of market and control mechanisms to achieve objectives.

- The guidance should show the various decisions to be made and questions that need to be resolved across planning, operations, and markets, as well as the dependencies and sequencing of these questions in the decision-making process.

- The DOE should investigate further via the EAC and other means how the various T-D interface models across North America will impact DOE efforts toward a grid resilience model.

Recommendation #4: The DOE should leverage the EAC membership by providing regular briefings for EAC members to share guiding architectural principles, present findings, and obtain additional direction (from the EAC) on the scope of the effort.

- The effort should complement and leverage the current activities of PNNL's Grid Architecture Initiative and the DSPx project. The products of the effort should include briefings and reports.

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Appendix A: Overview of Regional T-D Coordination and Issues

Region	Brief Description of T-D Relationship	T-D Interface Issues
East and Midwest (organized markets)	FERC-regulated ISO/RTO operates a wholesale electricity market and a NERC balancing entity. Utilities within the balancing region participate in the market as transmission operators, distribution operators, and retail sellers of electricity.	Defining relationship of distribution-connected generators, PV, and others to the wholesale market, and the data transfers and coordination.
Southeast	FERC-regulated, integrated utility generates, provides transmission services, provides distribution services, and sells electricity to retail, commercial, and residential load.	Utilities are working internally to define how they will coordinate within their companies, but all issues are internal.
ERCOT	State-regulated ISO operates a wholesale electricity market and a NERC balancing entity. Wire companies within the balancing region may not participate in the market. Load-serving entities registered with the PUC may sell energy at retail with very low entry requirements.	Defining relationship of distribution-connected generators, PV, and others to the wholesale market, and the data transfers and coordination. Currently, there is a risk of every transco and distribution company selecting different standards, resulting in chaos.
California	FERC-regulated ISO/RTO operates a wholesale electricity market and a NERC balancing entity. Utilities within the balancing region participate in the market as transmission operators, distribution operators, and retail sellers of electricity. Many customers groups are trying to build community choice aggregations with the support of the PUC.	Defining relationship of distribution-connected generators, PV, and others to the wholesale market, and the data transfers and coordination.
West excluding California	FERC-regulated, integrated utility generates, provides transmission services, provides distribution services, and sells electricity to retail, commercial, and residential load.	Utilities are working internally to define how they will coordinate within their companies, but issues are internal.
Norway	Close relationship between distribution companies and market operator because 40% of generation is on the distribution	

Region	Brief Description of T-D Relationship	T-D Interface Issues
	system. Wholesale spot market exists, but not a locational marginal price (LMP) market, so a single price exists for each time period across the market.	
Germany	Has four transmission system operators, decentralized dispatch, and the TSOs are responsible only for the ancillary services, not for the dispatch. The TSOs in Europe own and operate the network; there are no independent operators in place. All retailers and generators submit their expected load or demand and they have to balance that with the supply every 15 minutes, which is submitted to the TSOs. The TSOs contract the reserves and ancillary services to balance in real time after gate closure.	Overstimulation of DERs has resulted in an excess of distributed generation, mostly PV. Forecasting load is the responsibility of the DSOs; there are very few customers connected directly to the transmission network. The DSO might get a bill for the imbalance, which is distributed to its customers. There is no incentive for DSOs to be accurate, thus there is not a lot of transparency in DSO activities, i.e., excessive balancing services must be purchased from wholesale providers to compensate.
Australia	Wholesale market managed by AEMO; competitive retailers. Also has a regulated network. AEMO has locational or zonal price at each transmission connection point, fixed network costs, and wholesale cost; wholesale cost is derived from various generation sources. There is also a retail component.	Variable generation has pushed up the wholesale price; a lot of coal has been retired and replaced by intermittent sources. Volatility of supply resources led customers to DERs. Distribution generation is the "wild west" with no controls, so the wholesale generators must follow the retail DER.

Appendix B: List of Interviews

Interviewee	Region	Affiliation	Interview Date
Matt Tisdale	California/West	More Than Smart and Former California Public Utilities Commission	August 2, 2017
Lorenzo Kristov	California/West	CAISO	August 2, 2017
Shawn Schukar	Midwest	Ameren Transmission Co.	October 13, 2017
Jeff Bladen	Midwest	MISO	November 14, 2017
Hala Ballouz	ERCOT	Electric Power Engineers	September 1, 2017
Clayton Stice	ERCOT	ERCOT	September 6, 2017
Mike Bryson	East Coast (Organized)	PJM	October 23, 2017
Steve Herling	East Coast (Organized)	PJM	October 23, 2017
Billy Ball	East Coast (Non-organized)	Southern Company	November 6, 2017
Bente Hagem	International	ENTSO-E, Norway	November 14, 2017
Andreas Jahn	International	Regulatory Assistance Project, Germany	November 29, 2017
Mark Paterson	International	Horizon Power, Australia	December 7, 2017
John Phillpots	International	Energy Networks Australia	December 7, 2017
John McDonald	Non-operator	GE Digital Energy	November 16, 2017
Carlos Batlle	Non-operator	Massachusetts Institute of Technology	December 5, 2017