Operational Implications of the Convergence of Bulk Power & Distributed Energy

GridWise Architecture Council Transactive Energy Workshop

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Disclaimer

Ideas in this presentation are offered for discussion purposes only, and do not reflect the views or policies of the California ISO or Caltech Resnick Institute.
DER may reach 33% of Installed US Capacity by 2020

Effectively all incremental growth in capacity will come from customers

Sources: EIA, EPA, DOE, FERC, Carnegie Mellon, GlobalData
Responsive Distributed Energy Resource Values

<table>
<thead>
<tr>
<th>Use</th>
<th>Minimum duration of output energy (continuous)</th>
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<tbody>
<tr>
<td><strong>Balancing Authority &amp; Market Operations</strong></td>
<td><img src="image" alt="Diagram" /></td>
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<tr>
<td><strong>Transmission Operations</strong></td>
<td><img src="image" alt="Diagram" /></td>
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<tr>
<td><strong>Distribution Operations</strong></td>
<td><img src="image" alt="Diagram" /></td>
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<tr>
<td><strong>Customer</strong></td>
<td><img src="image" alt="Diagram" /></td>
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<td><strong>Energy Services</strong></td>
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Source: SCE, Adapted by Newport Consulting
Multiple DER Constituents

Market & control systems must be able to reconcile multi-party objectives & constraints related to the same distributed resource

Objectives & Goals
Decision Criteria & Processes
Constraints

Bulk Power System
Distribution Operations
Energy Financial Services
Customer
DER Equipment Firms
Energy Services Firms
Energy Related Services

Value Perception
Economic Value
Willingness & Ability
Transformational Operational Challenges
Challenges for Distributed Energy at Scale

- Spatial & Time Coordination
  - Redefine Roles and Interaction between Transmission and Distribution Operations
  - Redefine integration and coordination of controls and protection
  - Reassess “Market” Structures to ensure alignment of economic signals with system operations (broad use of term not just ISOs, but also bilateral and tariffs)

- Economic & Robustness Optimization
  - Full system trade-off analysis
  - Complexity vs. Simplicity
  - Risk Based Methods

- Coordination Needed Bet. Bulk Power, Distribution & Customers
  - Policy & Regulation
  - Infrastructure Planning & Investment
  - Information Exchange
Current policy, markets and operational trends are converging spatial and time dimensions more fully - while at the same time more tightly coupling across each dimension.

Requires:

• Planning Alignment
• Engineering/Design Alignment
• Operational Alignment
• Control Alignment
• Protection Alignment
Economic & Robustness Optimization

There is a fundamental trade-off between economic efficiency and robustness – we’re now also trying to resolve this system problem in a larger spatial and time context.

What are the range of options? An what is an acceptable set of solutions?
Coordination Across Domains

We are quickly reaching the limits of our ability to assume away the difficult issues. Or smoothing issues thru large numbers no longer masks the underlying problems

- Policy & Regulation
  - Energy Policy & Operational Reality – Systems View
  - Coordination bet FERC & State/Local Jurisdictions
  - NERC Reliability and Distribution (State/Local) Roles

- Infrastructure Planning & Investment
  - Redefine Integrated Resource Planning to more completely incorporate distribution and customer DER
  - Expand transmission planning to incorporate local distribution considerations
  - Adapt analogous transmission planning methods to local area distribution planning

- Information Exchange
  - Planning information (Engineering, Benefit-Cost, Regulatory)
  - “Market” Information (Pricing & Settlement)
  - Operational Information (Situational Awareness, Decision Support & Control Feedback)
Transmission – Distribution Interface

- In the high-DER electric system:
  - Resources on distribution system are more diverse & variable
  - Flows on distribution system are complex & bi-directional
  - Net flows across PNodes may be bi-directional

- Should the PNode remain the operational boundary? The market boundary?
  - Minimum size threshold for DER in wholesale markets?
  - Must-offer, NQC & other RA rules for small variable DER?
  - Do existing RA concepts work in high-DER world?
  - More granular LMPs to reflect distribution system constraints?
  - Joint transmission-distribution system planning?

- What should be the roles and responsibilities of UDCs in a high-DER world?
  - State regulator & UDC lead multi-stakeholder distribution planning
  - Retain statutory role as distribution owner-operator
  - Real-time sub-transmission & distribution operations (also transmission in non ISO/RTO regions)
  - Distribution grid services pricing & operational coordination
  - DER Energy market coordination
  - DER Transaction management

Adapted from CAISO/Lorenzo Kristov
Transmission – Distribution Interface Models

Two conceptual bookends for framing the questions.

- **Bookend A:** T+D comprise a fully integrated system, with one system operator that performs scheduling, real-time balancing, integrated markets, planning, etc. => traditional T-D boundary is largely irrelevant for purposes of markets and operations.

- **Bookend B:** T and D are separate systems that meet at well-defined T-D interface points (e.g., PNodes), with a transmission system operator for the transmission grid and wholesale markets, and new, separate entities to operate & balance the distribution systems.

- Bookends are expressed as “pure” or extreme models in order to emphasize their differences
  - But both are plausible futures, so it is prudent to figure out and help design how they would work in practice
  - Not mutually exclusive; may likely co-exist for many years
  - Bookends represent conceptual “end states” – without yet considering possible transition paths to these states
Transmission – Distribution Interface

Bookend B shifts distribution-level operational & market roles & responsibilities from ISO/RTO to DSO.

<table>
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<tr>
<th>Bookend A</th>
<th>Bookend B</th>
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| • ISO/RTO schedules and dispatches integrated T+D system to maintain real-time balance & reliability  
• ISO/RTO has visibility & dispatches all DER above a low size threshold (e.g., 50 or 100 kV)  
ISO/RTO provides real-time services (balancing, load following, frequency, etc.) for DER and loads as well as for grid-connected resources | • ISO/RTO operates transmission grid only (i.e., up to the PNode)  
• Distribution system operator (DSO) operates distribution system below each PNode  
• PNode is similar to an intertie  
• DSO is similar to a micro-grid or load-following MSS  
ISO/RTO provides real-time services only for grid-connected resources  
• DSO provides RT services for DER and loads  
• DSO at each PNode is comparable to a Scheduling Coordinator from ISO/RTO perspective |

Source: CAISO/Lorenzo Kristov
Distribution System Operator Model B

Bulk Power System

- Distribution Planning & Investment
- Active Network Operations
- Distributed Market Coordination

Distributed Resources
Retail Energy Transactions
DSO Functional Responsibilities

Bulk Power System

ISO P-node/Transmission-Distribution Substation

DSO

Distribution Planning & Investment

Collaborative Distribution Planning

Utility investment, ownership and maintenance of distribution infrastructure including core advanced technologies (e.g., certain storage)

Distribution Infrastructure

Utility system operations to ensure safety, reliability, power quality while managing bi-directional power flows and various services across the distribution system to and from a P-node

Active Network Operations

Grid Services Coordination

Utility operationally aggregates and dispatches various DER providing ancillary services for bulk power and distribution system operations. Function includes valuation of various distribution services & distribution constraint value

Transaction Management

Schedule coordination of bi-directional energy transactions across a P-node and within a distribution system. Includes scheduling, measurement, verification and settlement. This role replaces the traditional schedule coordinator function to ensure reliable system operations across T&D boundaries

Distributed Market Coordination

Distribution Planning & Investment

Regulatory-utility led Scenario based Multi-Stakeholder Process to Address:
1. DER Public Policy
2. Reliability
3. Unique Project Economics

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Need to revise distribution planning process to better evaluate value of DER and distribution infrastructure requirements

Scenario planning methods are better suited than just evaluating DER interconnection project queues

Planning should be done on a P-node (or equivalent) basis – evaluate distribution planning on the integrated distribution system below a p-node and across the node.

Adapt 2010 CA transmission planning model

- DER policy scenario – assess DER and distribution infrastructure investment needed to achieve DER policy objectives
- Reliability scenario – assess DER and distribution infrastructure investment needed to achieve reliability & resilience objectives
- Specific DER project economics – assess specific benefit-cost of individual distribution interconnection projects
Distribution Operations: Active Network Operations

- Power Flow Coordination
  - Feeder Switching Coordination
  - Phase Balancing
  - Protection Coordination
- Distribution Optimization
  - Asset Utilization
  - Overload Management
  - Power Factor Management
- Power Quality & Reliability
  - Dynamic Volt/VAr Management
  - Harmonics Dampening
  - Outage & Restoration Management
- Safety
  - Unsafe Line Backfeed
Distributed Market Coordination

- Operational aggregation of DER services providing bulk ancillary services and distribution operational services
- Engineering-economic valuation of distribution benefits/constraints
- Schedule coordination across p-node (T-D interface) and within distribution system
- Transaction settlement process to reconcile the grid service transactions, payments and fees between various parties (note: this does not include settlement of private party bilateral contracts)