The transmission-distribution interface in a distributed energy future

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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.
Proliferation of diverse distributed energy resources (DER) challenges traditional electric industry model.

- **Focus on the ISO/RTO context**
  - ISO/RTO operates transmission grid & wholesale markets
  - Independent of utility distribution companies (UDCs)

- **Focus on the transmission-distribution interface**
  - Conventional T-D boundary is the LMP pricing node or “PNode” – substation where meshed transmission network meets a radial distribution system
  - ISO/RTO delivers energy over the grid from generators to load-serving PNodes
  - UDCs deliver energy from PNodes to end-use customers
Distributed energy resources (DER) are supply and demand-side resources connected to the distribution system.

- Distributed generation (DG)
  - Rooftop solar PV (behind the meter)
  - Community-scale and commercial renewables
  - Combined heat and power (CHP)
- Storage facilities
- Electric vehicles and charging stations
- Energy efficiency, demand response resources & energy management programs
- Combinations of any of the above
  - Micro-grids, virtual power plants
DER are growing in volume and diversity in response to multiple forces of change.

- Policies to expand renewable energy and reduce the environmental impacts of energy
  - AB32 – greenhouse gas reduction & 33% RPS
  - California Solar Initiative and net energy metering (NEM)
  - Storage and DG procurement targets
- Greater availability and declining costs of diverse new technologies
  - Inexpensive solar PV; electric vehicles; residential storage; micro-grid systems; building automation systems; small-to-medium scale DG and “community” renewable resources
- Customer desires for greater choice and control
  - Efficiency; automated demand response
  - Desire for local resilience to major disturbances
The growth of DER is changing the electric industry in significant, unprecedented ways.

- More small DER are counting for resource adequacy and participating in ISO markets and dispatch
  - Sheer numbers of small resources (< 0.5 MW) will present challenges for metering, modeling and real-time operation
  - Combinations of different DER types form a “virtual power plant” that participates as a single resource
- Increasing share of end-use energy is produced locally
  - Without relying on the ISO grid (DG)
  - In the near future, without having to rely on the distribution system (rooftop PV plus storage)
- Micro-grids and local systems will be able to “island”
  - Compare today’s load-following MSS
These changes require substantial re-thinking of the traditional ways of doing business.

- Revenues based on kWh/MWh are declining
  - Near zero marginal cost of renewable energy
  - Behind-the-meter and net-energy-metered production

- Infrastructure challenges – Planning the redesign of distribution systems to meet the high-DER future

- Operational & market challenges – How to re-think and redesign the T-D interface for the high-DER future?
  - PNode as an operational boundary?
  - PNode as a market boundary?

- Regulatory challenges – Current roles & responsibilities of ISO/RTO vis-à-vis UDC are well established in regulation
High DER penetration makes traditional definition of transmission-distribution interface obsolete.

• 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?

• How best to redefine roles and responsibilities of ISO and UDCs for the high-DER world?
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
Bookend B shifts distribution-level operational & market roles & responsibilities from ISO/RTO to DSO.

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

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<td>• ISO/RTO provides real-time services only for grid-connected resources</td>
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<td>• DSO provides RT services for DER and loads</td>
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<td>• DSO at each PNode is comparable to a Scheduling Coordinator from ISO/RTO perspective</td>
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Other features may characterize the future high-DER, high-renewables power system.

• New revenue model emphasizes balancing & flexibility services, de-emphasizes sales of kWh/MWh
  – DSO’s business is open access distribution service, reliable operation, interconnection, distribution system planning
  – Settlements reflect cost of balancing variability as well as net kWh/MWh – both ISO-to-DSO and DSO-to-DER/loads
  – DER/loads that add variability are charged for RT services; those that help manage variability may be paid
  – DSO may run local markets for balancing/reserves/regulation

• Greater coordination & integration across the west
  – RT energy imbalance markets over multiple states
  – DA congestion management eliminates unscheduled loop flows
  – Efficient west-wide grid operation may enable access to renewable-rich areas without new grid infrastructure
The future electric system may look a lot like the Internet: distributed, shared, decentralized

- Policy initiatives expand renewables & efficiency
- DER proliferate as demand and performance rise while costs decline
- End-users get more energy services without using kWh
- Majority of kWh consumed are produced locally
- Local electric systems become self-optimizing, resilient
  - Capable of islanding in response to disturbances
- ISO/RTO grids and markets coordinate and balance energy needs & surpluses of distribution-level systems
  - Provide access to renewable-rich areas
- DSO offers potential model for traditional UDCs to thrive in the high-DER future.