California ISO
Shaping a Renewed Future

The transmission-distribution interface in a distributed energy future

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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.

Bookend A	Bookend B
• 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 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 (balancing, load following, frequency, etc.) for DER and loads as well as for grid-connected resources	• 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

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.