Making the Distribution Grid More Open, Efficient and Resilient

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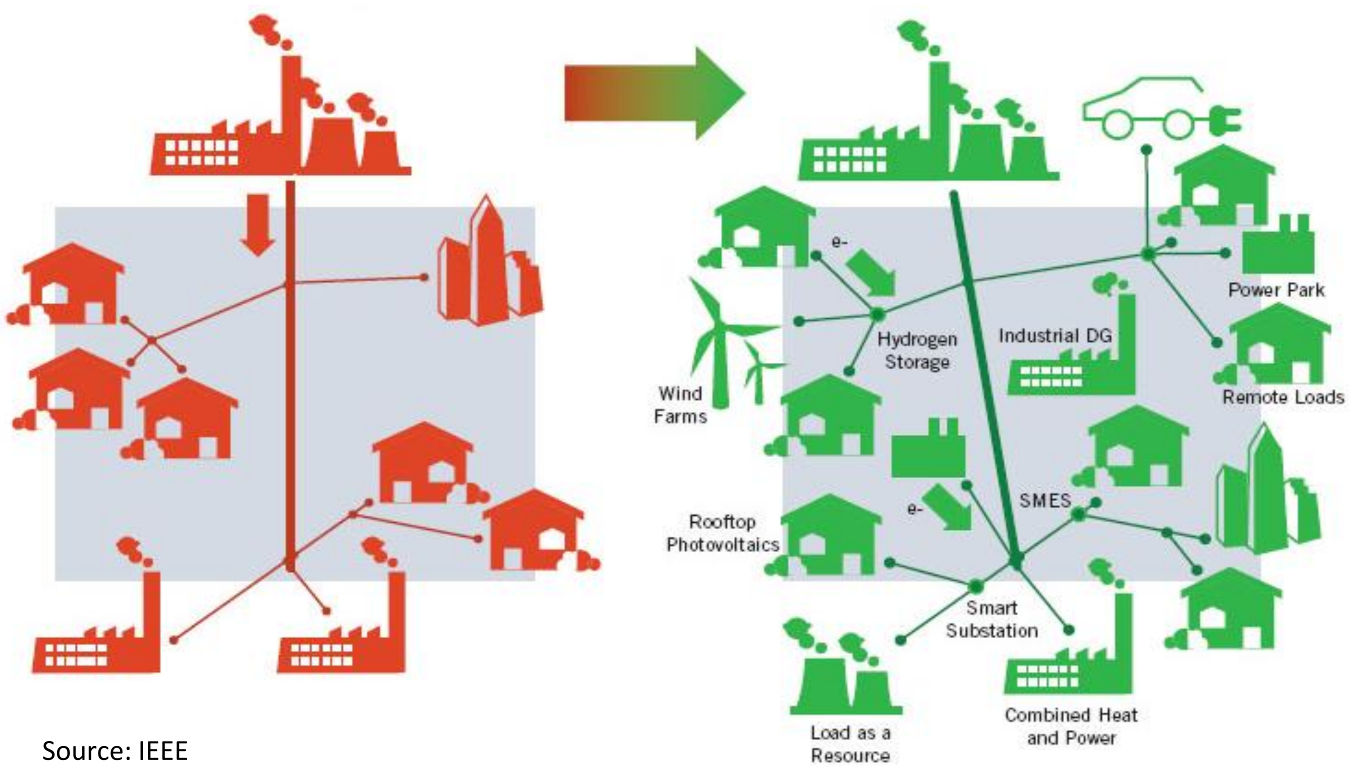
Grid Evolution: One-way Road to Grid of Things

Grid increasingly becoming a multi-directional network interconnecting millions of intelligent consuming devices and flexible DER and back-up generation



Source: IEEE

Operating such a system requires greater situational visibility and collaboration with customers and their services providers

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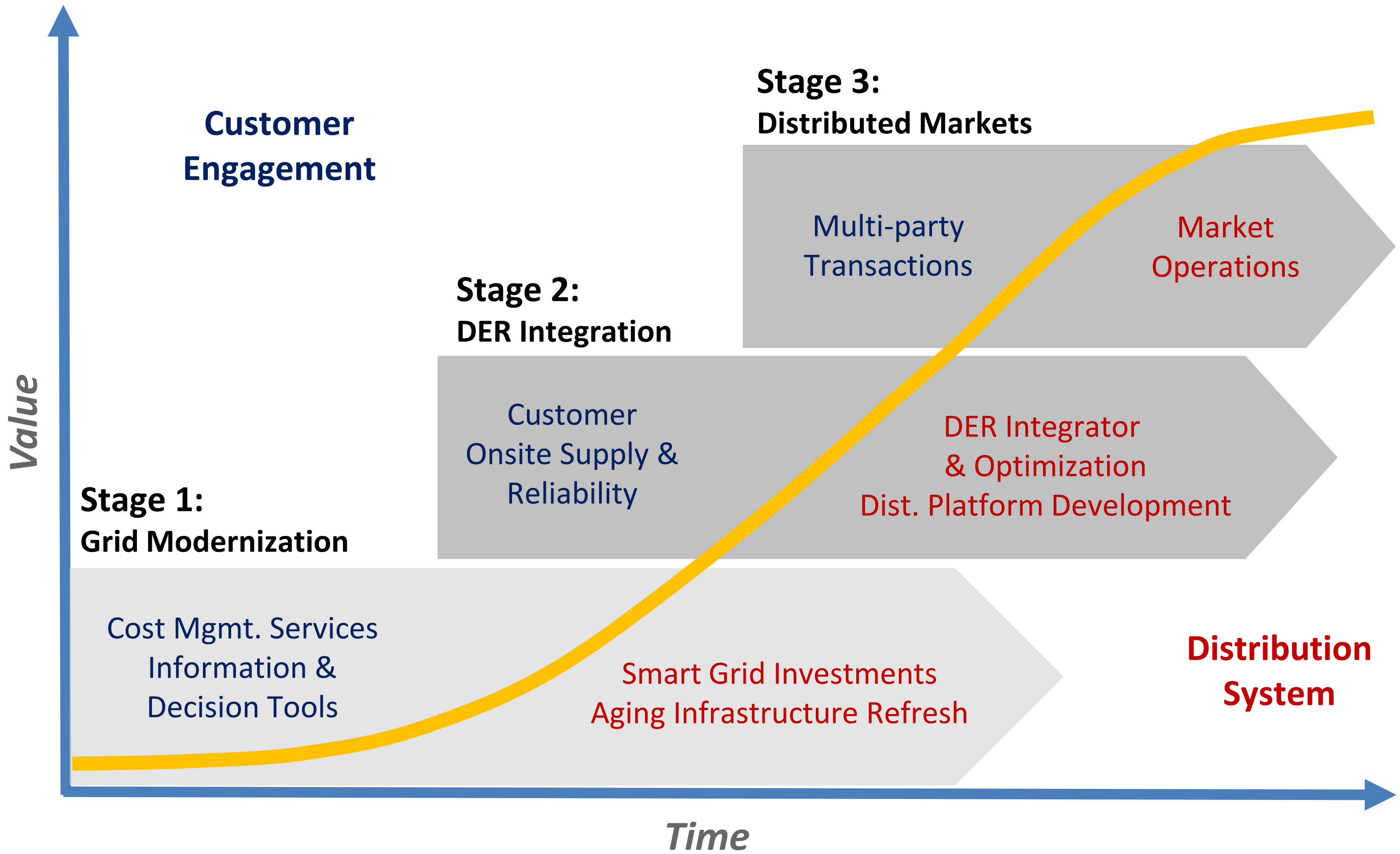
Evolution of Customer & Distribution System

3 Stages of Evolution as DER Adoption Grows & Market Opportunities Expand



How Will We Develop & Operate This Grid?

Focus on Customer Value & New User Needs

- Integrated Grid Planning
  - DER Hosting Capacity
  - Locational Benefits
  - Integration w/Trans. & Resource Planning
- Grid as an Open Platform
  - Leverage Current Investments
  - Evolve to Create "Plug & Play" System
- Integrated Distribution Operations
  - Manage distributed power flows
  - Coordinate physical flows across T-D interface
- DER Market Opportunities
  - Expanding opportunities to provide services
  - Market structures vary and should align with parties' respective needs

Changes to Traditional Distribution Lifecycle Management Processes Required

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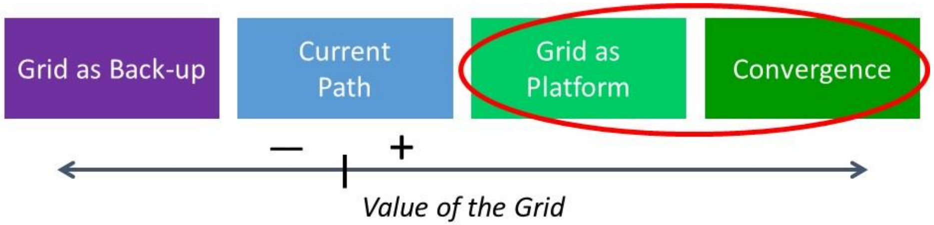
What Distribution Grid Do We Want?



Current Path

Distribution system refresh underway is increasing capacity
- Continued replacement of aging electric infrastructure
- Refresh involves upgrading to higher voltage levels in areas with high DER potential
- New design practices incorporate larger sizes for wire and transformers that improve reliability & DER integration

More Resilient/Reliable/Safe & Visible
- Extending distribution automation to improve fault isolation and service restoration capabilities
- Continued upgrades on distribution protection systems (substation communications and analog to digital relays)
- Integration of field sensors (smart meters, other sensors) into grid operational systems that enable situational intelligence
- Digitization of field asset information (completing the analog to digital transition)

Open Grid Platform

Seamless:
- Enable multi-directional real & reactive power flows
- Enable transactions across distribution with utility distribution company, bulk power operations and wholesale market

Open & Transparent:
- Low barriers to access physical connections & value monetization opportunities
- Streamlined interconnection rules and processes
- Transparent processes for planning and operations
- Access to distribution planning & operational information (qualified access)
- Transparent locational value determination and monetization

Network & Convergent Value:
- Physical and operational qualities that yield greater safety and reliability benefits
- Qualities that may create greater customer/societal value from each interconnected DER ("network effects")

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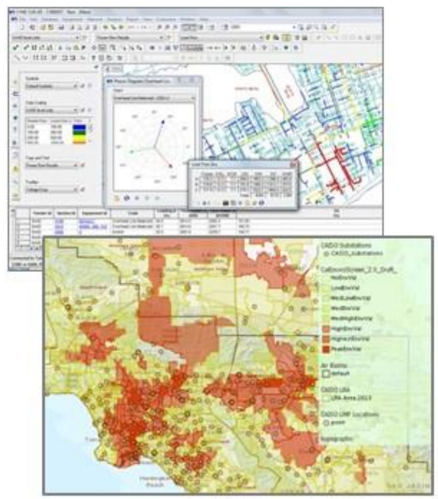
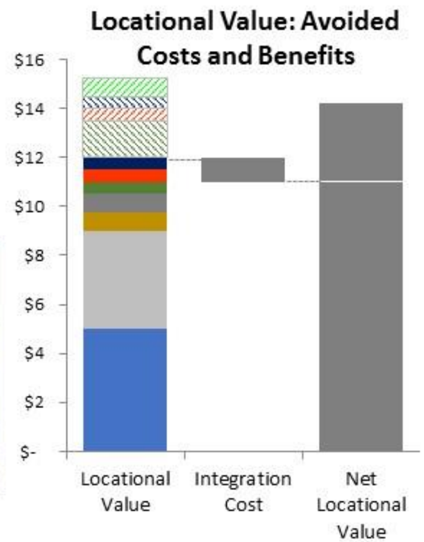
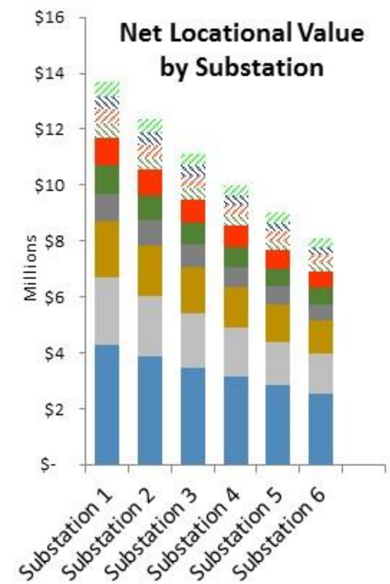
Distribution Planning Process

Integrated Grid Planning Required – California Dist. Resources Plan Example

Identify DPA & Substations → Perform Hosting Capacity & Scenario Analyses → Calculate Locational Net Value → Rank Substations by Locational Net Value







Shift from Deterministic Engineering Analysis + System level Benefits Analysis Toward Dynamic Engineering Methods with Locational Benefits Incorporated

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Integrated System Operations Evolution

A spectrum of possible designs can be envisioned in terms of the complementary roles of DSO and TSO.

Relevance of T-D boundary

Least ←→ Most

Model A:
TSO optimizes the whole integrated system – all the way down into the distribution system including managing coordination of all DER services schedules

DSO only responsible for safe and reliable distribution operations

Model B:
TSO optimizes only the transmission system – sees multiple aggregate or "virtual" resources by Aggregators & DSO at each T-D interface.

DSO responsible for physical coordination of DER services to T-D Interface and safe & reliable operation of distribution grid

Model C:
TSO optimizes only the transmission system – sees a single aggregate or "virtual" resource at each T-D Interface managed by DSO

DSO responsible for physical coordination of all DER services to T-D Interface and safe & reliable operation of distribution grid

Adapted from: L. Kristov CAISO

Distributed Market Design

Distribution Market Design has 3 Components

Customer, Environmental & Grid Values

Service Definitions & Requirements

Market Structures Aligning Parties' Req.'s

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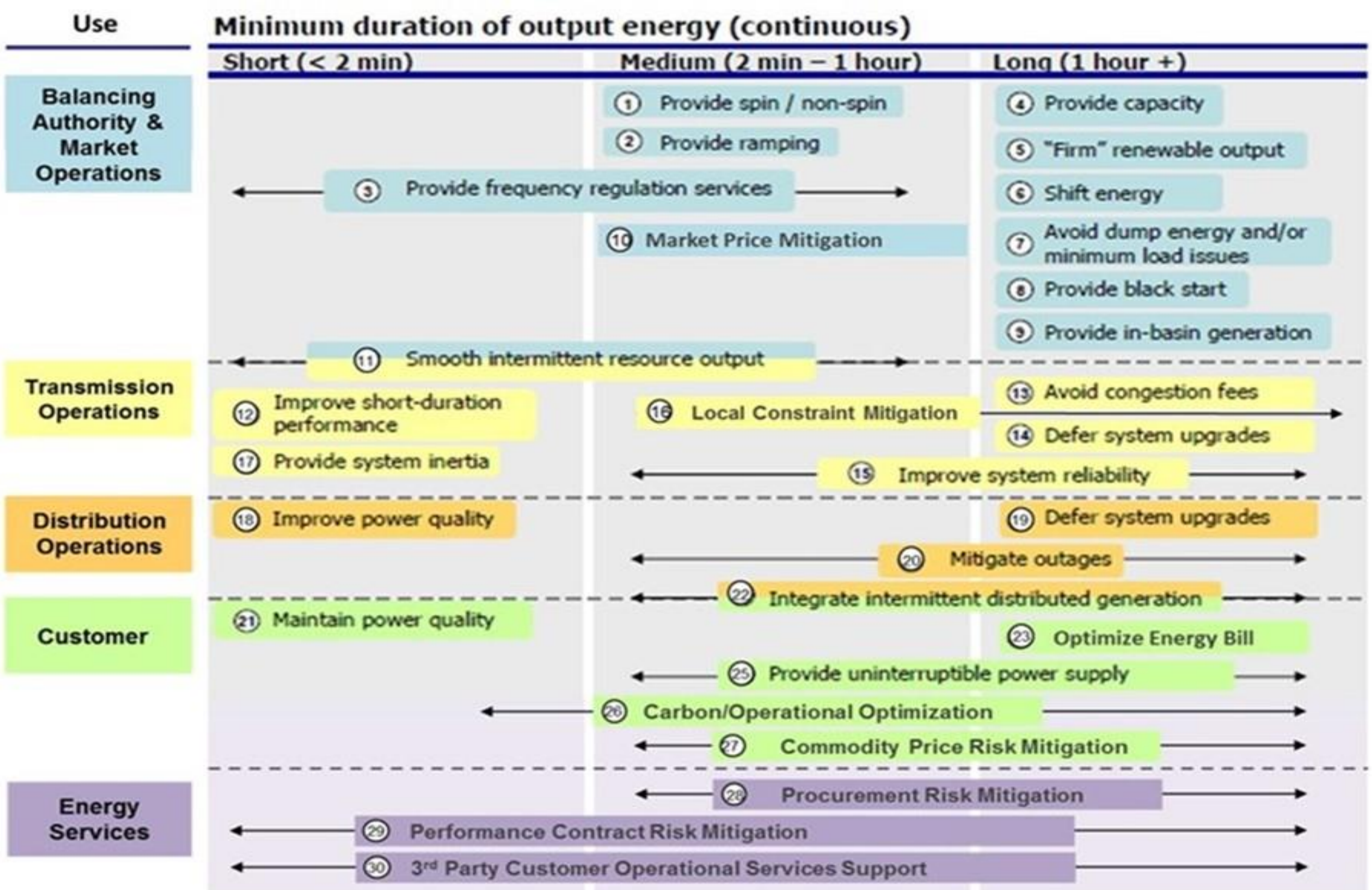
DER Value Components (MTS example 1 of 2)

Objective is to define a mutually exclusive and collectively exhaustive (MECE) list irrespective of whether these could be valued or monetized today, or if the value is part of utility revenue requirements.

	Value Component	Definition
Distribution	Subtransmission, Substation & Feeder Capacity	Reduced need for local distribution system upgrades
	Distribution Losses	Value of energy due to losses between wholesale transaction and distribution points of delivery
	Distribution Power Quality + Reactive Power	Improved transient & steady-state voltage, reactive power optimization and harmonics
	Distribution Reliability + Resiliency+ Security	Reduced frequency and duration of individual outages & withstand and quickly recover from large external natural, physical and cyber threats
	Distribution Safety	Improved public safety and reduced potential for property damage
Customer, Societal & Environmental	Customer Choice	Customer & societal value from robust market for customer alternatives
	CO2 Emissions	Reductions in federal and/or state CO2 emissions based on cap-and-trade allowance revenue or cost savings or compliance costs
	Criteria Pollutants	Reduction in local emissions in specific census tracts
	Health Impacts	Reduction in societal health costs associated with GHG emissions
	Energy Security	Reduced risks derived from greater supply diversity
	Water Use	Synergies between DER and water management (electric-water nexus)
	Land Use	Environmental benefits & avoided property value decreases from DER deployment instead of large generation projects
	Economic Impact	State or local net economic impact (e.g., jobs, GDP, tax income)

DER Services Opportunities

Potential for DER Provided Services Across Power System



Source: SCE, Adapted by Newport Consulting

Distributed Market Structures

Market Structures Need to Align Grid Operational & DER Commercial Requirements
Plus, Distribution Provider Services Need to Align with DER Market Reqt's

	Service Name	Description	Performance Requirements	Standard Tariffs & Riders	Dynamic Rates	Flexible Service Pricing	RFP	Auctions	Bi-lateral Forward Markets	Spot Markets
DSP Services										
DER Services										

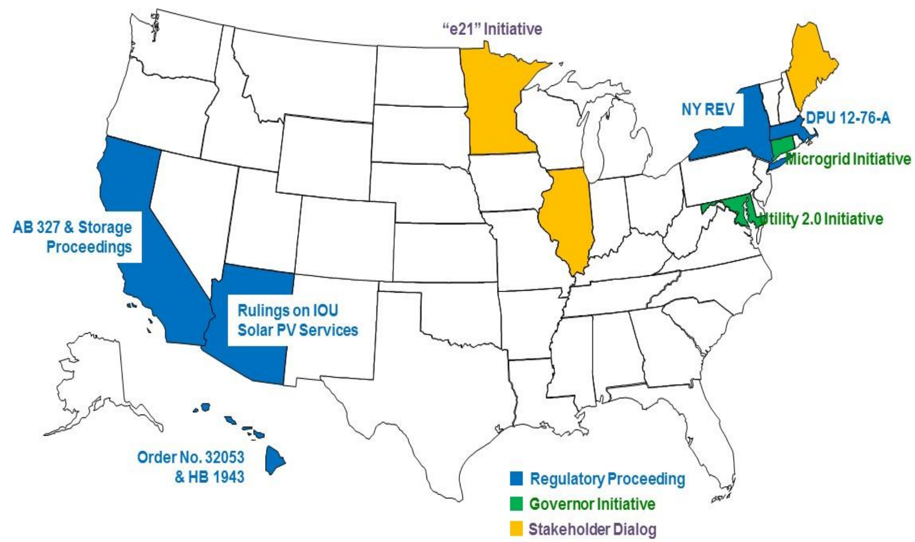
States Turning Concepts Into Practice

Several states have open proceedings or having preliminary stakeholder dialogs

- **New York** REV
- **California** DER/EV related proceedings
- **Hawaii** Grid Modernization & DER integration
- **Arizona** Utility DER services & ownership

Focus of Regulation & Advocacy

- **Distribution as an enabling network**
  open access platform & distribution system operations as market facilitator
- **Expanding customer services**
  opportunities for utilities to facilitate and/or provide DER, microgrid and other competitive customer services
- **Reforming Regulation**
  - Performance based ratemaking (extensive metrics)
  - Rate case process changes (e.g., future test year)
  - NEM/TOU Rate reform



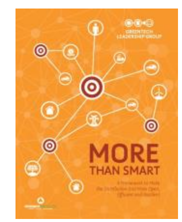
> ***"Utilities must transform into "market-makers" who solve problems at the edge of the system"***
> Audrey Zibelman, Chair, NY PSC May 2014

MTS Background

More Than Smart Evolution

Discussion of a holistic systems engineering approach to enable scaling renewable and distributed resources in California began at Caltech-Resnick Institute ***Grid2020*** workshop in Fall 2011 – this provided a foundation for the ***More Than Smart*** effort

Oct 2011	Sep 2012	Oct 2013	Jun 2014	Jul 2014	Aug 2014	Oct 2014
Grid2020 Workshop	**Grid2020** Caltech Report	**MTS Workshop 1**	**MTS Workshop 2**	**MTS** Working Group	**MTS** Paper	**MTS Workshop 3**



GREENTECH LEADERSHIP GROUP

www.resnick.caltech.edu

www.greentechleadership.org

California Distribution Resources Plan http://www.cpuc.ca.gov/PUC/energy/drp/

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More Than Smart Paper Overview

- Purpose:
  - Continue the dialog on the evolution of CA's power system focusing on its role & attributes to enable customer benefits and public policies related to cleaner and distributed resources
- Participants:
  - Developed originally from MTS workshop 1 (~75 people) discussion notes
  - Further refined by feedback from a subset of people (~20) representing a cross section of stakeholders
- Paper:
  - Focus on distribution system holistically from a full lifecycle perspective
  - Broader than PUC 769 scope to explore the interrelationship to other aspects of distribution and interrelationship to customers, DER development, markets, & transmission
  - Provide a framework for the many aspects to consider in development and operation of an enabling distribution platform for customer participation and DER at scale

Distribution Planning

Guiding Principles	Potential Requirements
P1: Scenario-driven integrated planning analysis framework	P1a: Framework should identify all relevant analysis and modeling interdependencies and related engineering-economic trade-offs P1b: Planning should use scenario driven "futures" using a set of common parameters including customer DER adoption, and other critical factors P1c: Planning should establish baseline functionality of current infrastructure and designs
P2: Standardized methodology and tools for distribution planning	P2a: Planning should be performed using a consistent set of accepted engineering and economic methodologies, but remain vendor and modeling technology neutral P2b: Engineering models and tools should address all relevant power system characteristics and dynamics for a well defined distribution area and inter-related local transmission system consistent with best practice
P3: Greater access to grid operational and market planning data	P3a: Utility asset and operational data used for distribution planning should be accessible to 3rd parties and researchers under certain qualifications and subject to confidentiality and security conditions. P3b: Market planning data from DER developers and services firms will be available to utilities and research institutions for relevant distribution and bulk power system planning under specific conditions and subject to confidentiality
P4: Integrated multi-stakeholder distribution planning process	P4a: Planning scope should involve relevant stakeholders, including representatives of customers, in process P4b: Stakeholder engagement should not create a bottleneck to planning process

Grid Design-Build

Guiding Principles	Potential Requirements
P5: Evolve grid to an open network platform	P5a: Create a node-friendly distribution network that is open, visible, flexible, reliable, resilient and safe P5b: Incorporate full operational risk mitigation considerations into physical designs and protection and control systems leveraging DER/microgrid
P6: Employ flexible designs & layered architecture	P6a: Leverage systems engineering methods to create more flexible designs to address differences in technology lifecycles to mitigate stranded costs P6b: Employ layered, distributed architecture for operational systems to address scale issues involving integration of edge devices
P7: Align deployment timing with customer and policy needs	P7a: Leverage scenario based planning to identify low risk capital investments to keep pace with needs P7b: Identify no regrets utility distribution investments needed in any scenario
P8: Align utility technology adoption	P8a: Establish well defined technology adoption on-ramps into operational deployment P8b: Align R&D projects, Smart Grid Roadmaps with rate case requests for distribution capital investment

Integrated Systems Operations

Guiding Principles	Potential Requirements
P9: Provide safe and reliable distribution service	P9a: Define minimal utility DSO functional related responsibility and accountability for physical operations of a local distribution area P9b: DSO should provide T-D Interface reliability coordination with CAISO for a local distribution area. P9c. DSO should provide physical coordination with the TSO for energy transaction across the T-D interface.
P10: Provide neutral marketplace coordination	P10a: The DSO paradigm should support public policy energy and environmental objectives P10c. The DSO paradigm should enable the best new technologies to emerge and succeed, rather than picking winners through an administrative process.
P11: Situational awareness and operational information exchange	P11a: Operational information and communication standards are needed for "plug and play" DER integration P11b: DSO operational system architecture and related requirements should be developed to guide implementation P11c: T-D operational information interface requirements should be assessed current CAISO protocols and standards
P12: Avoid conflicts of interest through functional separation	P12a: DSO operations should follow similar standards of conduct as those imposed by FERC on transmission operations . This requires CPUC distribution SOC development. P12b: Define those optional market facilitation services that may be provided by DSO and/or 3rd party under specific conditions

DER Market Structures

Guiding Principles	Potential Requirements
P13: Fully address DER participation in wholesale markets and resource adequacy	P13a. Wholesale opportunities for flexible DER should be fully expanded to support bulk power operations. P13b. Performance requirements should align with identified value to provide reasonable results for all stakeholders including net benefits for ratepayers.
P14: Unbundle distribution grid operational services	P14a. Identification and prioritization of differentiated distribution grid operational services should fully support grid operations, asset utilization, capital investment and meet policy requirements P14b: Definition of service performance characteristics and related performance requirements should use technology neutral methods
P15: Enable transparent DER value identification and monetization	P15a. Distribution services value identification and monetization methods should provide reasonable results for all stakeholders including net benefits for ratepayers. P15b. Distribution tariffs and/or procurements for flexible DER should be fully expanded to enable DER to support grid operations.
P16: Open access and low barriers to DER participation	P16a. Participation rules and processes should enable participation levels consistent with California policy objectives. P16b. The cost of integrating flexible DER should not be a barrier to participation. Alternative solutions should be considered. P16c. Transaction processes including scheduling, verification and settlement should not be a barrier to participation.

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DER Value Components (CA MTS example 2 of 2)

	Value Component	Definition
Wholesale	WECC Bulk Power System Benefits	Regional BPS benefits not reflected in System Energy Price or LMP
	Wholesale System Energy Price	Estimate of long-term marginal wholesale system-wide value of energy
	Wholesale Energy	Reduced quantity of energy produced based on net load
	Resource Adequacy	Reduction in capacity required to meet Local RA and/or System RA reflecting changes in net load and/or local generation
	Flexible Capacity	Reduced need for resources for system balancing
	Wholesale Ancillary Services	Reduced system operational requirements for electricity grid reliability including all existing and future ISO ancillary services
	RPS Generation & Interconnection Costs	Reduced RPS energy prices, integration costs, quantities of energy & capacity
	Transmission Capacity	Reduced need for system & local area transmission capacity
	Generation/DER Deliverability	Increased ability for generation and DER to deliver energy and other services into the wholesale market
	Transmission Congestion + Losses	Avoided locational transmission losses and congestion as determined by the difference between system marginal price and LMP nodal prices
	Wholesale Market Charges	LSE specific reduced wholesale market & transmission access charges