



Modernizing transmission- distribution interface coordination for a high-DER future

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Energy Advisory Committee Meeting
March 29, 2017



Growth of DER and potential distribution-level markets call for an updated coordination framework.

- ❖ The electric industry – at state, national and global levels – is undergoing broad transformation characterized by
 - Shift to renewable energy resources and away from conventional fossil-fuel generation at all scales
 - “Grid edge” adoption of diverse distributed energy resources (DER) and a trend toward decentralized power systems (e.g., microgrids)
 - Decline of the traditional centralized, one-way power flow paradigm and commodity-based revenue models and rate structures
 - Potential for distribution-level “peer-to-peer” markets
 - New roles for distribution utilities (DOs) or new entities becoming distribution system operators (DSOs)
- ❖ First and foremost, the next system must be reliable and meet 21st century objectives for sustainability, resilience, efficiency
- ❖ Crucial to success will be the coordination between transmission and distribution systems and markets

DER business models look to provide services and earn revenues at multiple levels of the system.

“DER” = all energy resources connected at distribution level, on customer side or utility side of the customer meter

- Plus communications & controls to aggregate & optimize DER
- ❖ Behind the end-use customer meter
 - Time of day load shifting, demand charge management, storage of excess solar generation
 - Service resilience – smart buildings, microgrids, critical loads
- ❖ Distribution system services
 - Deferral of new infrastructure
 - Operational services – voltage, power quality
- ❖ Transmission system and wholesale market
 - ISO spot markets for energy, reserves, regulation
 - Resource adequacy capacity
 - Non-wires alternatives to transmission upgrades
- ❖ Bilateral energy contracts with customers, DOs & LSEs
- ❖ Peer-to-peer transactions, via distribution-level markets

In early 2016 the ISO began working with distribution utilities and stakeholders to identify operational coordination needs and solutions at the T-D interfaces for a high-DER future.

Preliminary observations and recommendations include:

1. Coordination framework must engage three entities: ISO, distribution utility (DO) and DER provider
2. Specific near-term 2017 enhancements are needed to reliably integrate DER aggregations in the ISO market
3. Efforts must continue as DER growth evolves
4. Longer-term arrangements should be automated to deal with high levels of DER
5. Focus on operations makes this relevant to all DOs – IOUs, municipals, market or non-market areas

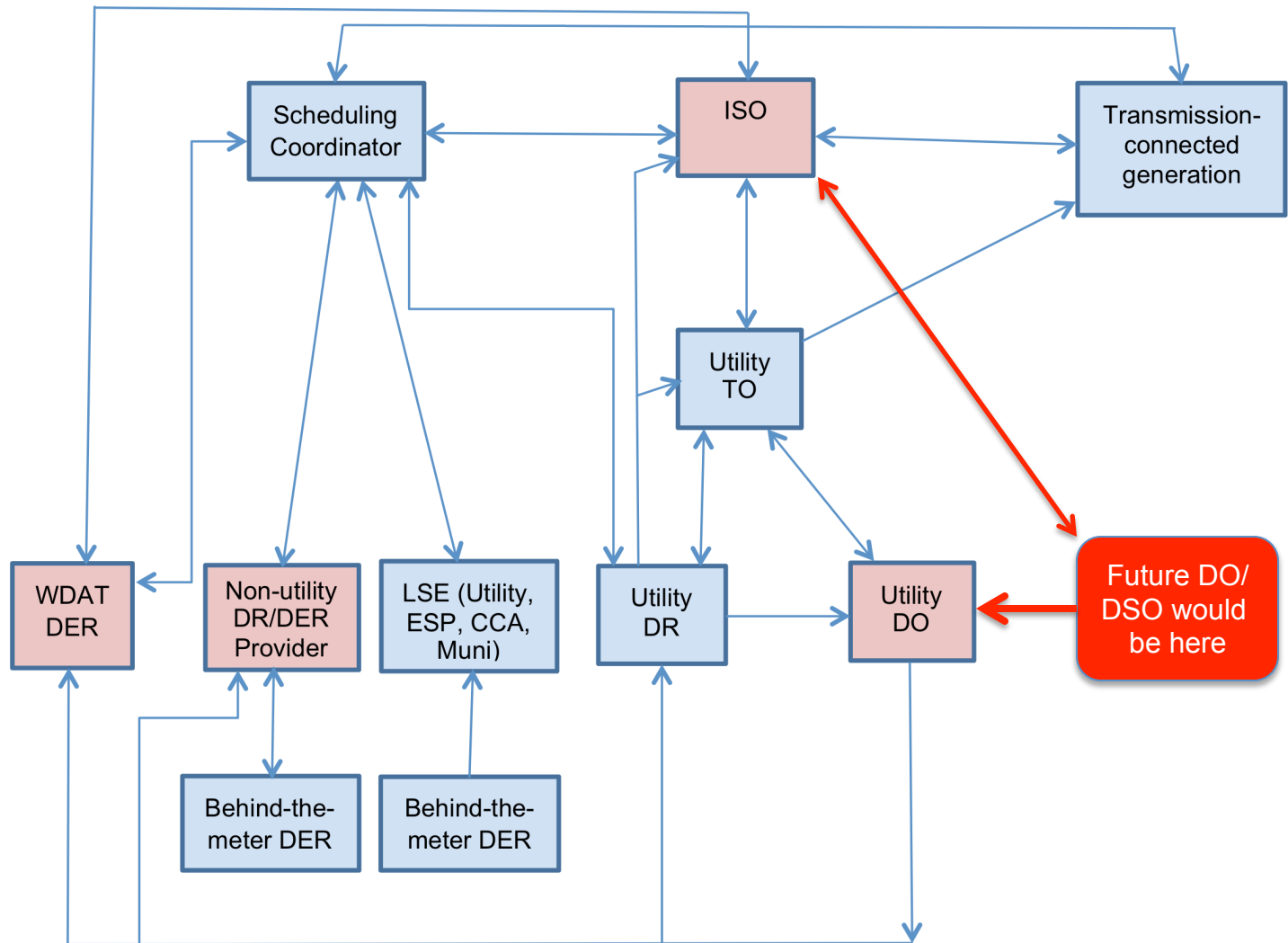
Each entity's objectives and responsibilities drive needed tools, information flows and procedures.

- ❖ ISO's primary DER concern is at the T-D interface or p-node
 - Predictability/confidence re DER responses to ISO dispatch instructions
 - Short-term forecasts of net interchange at each T-D interface
 - Long-term DER growth scenarios for transmission planning
- ❖ DO's concern starts with reliable distribution system operation
 - Visibility/predictability to current behavior of DER
 - Ability to modify behavior of DER via instructions or controls as needed to maintain reliable operation
 - Long-term DER growth scenarios for distribution planning
- ❖ DER provider/aggregator is concerned with business viability
 - Ability to participate, in a non-discriminatory manner, in all markets for which it has the required performance capabilities
 - Ability to optimize its choice of market opportunities and manage its risks of being curtailed for reasons beyond its control

System components (boxes) and structures (arrows) will determine system performance.

Diagram reflects today's demand response (DR) coordination. Today the ISO and Utility DO do not exchange information or coordinate activities for real-time operation.

Relationships of **red boxes** are crucial for T-D coordination with High DER.



Recommended 2017 enhancements to ensure reliable integration of DER aggregations in the ISO market.

- DO should provide advisory information to DER providers about system conditions that will affect their operation
- The ISO should provide day-ahead DER schedules to the DO, to allow opportunity for the DO to check feasibility
 - eventually extent to real-time dispatch instructions
- The DER provider should communicate constraints on its resources' performance to the ISO
- DER aggregator should work with DO early in the resource implementation process to identify and address any concerns about operational impacts of a DER aggregation
- DOs should pursue a pro forma “aggregation agreement” with DER providers

New T-D coordination framework for high DER must address several essential areas and functions.

Area of Activity	Challenges of High-DER	What's Needed
System operations	<ul style="list-style-type: none"> • Diverse DER behaviors & energy flows, esp. with aggregated virtual resources • Hard to forecast impacts at T-D interfaces • DO is not in the loop on DER wholesale market transactions • Multi-use DER may receive conflicting dispatches/signals (from DO and ISO) 	<ul style="list-style-type: none"> • Distribution grid real-time visibility • Real-time forecasting of DER impact at each T-D substation • Coordination procedures between ISO, DO and DER re wholesale DER schedules & dispatches • Dispatch priority re multiple uses
T & D infrastructure planning	<ul style="list-style-type: none"> • Long-term forecasting of DER growth & impacts on load (energy, peak, profile) • DER seek to offset T&D upgrades • Distribution grid modernization needs 	<ul style="list-style-type: none"> • Align processes for T&D planning and long-term forecasting • Specify required performance for DER to function as grid assets • Modernize grid in logical stages for “no regrets” investment
System reliability & resilience	<ul style="list-style-type: none"> • High DER may make traditional top-down paradigm obsolete 	<ul style="list-style-type: none"> • Develop new models to “layer” responsibilities for reliability
Market issues: <ul style="list-style-type: none"> • Wholesale v retail • Monopoly v competition 	<ul style="list-style-type: none"> • When does DER volume in wholesale market become too costly? • Unclear boundary between competitive v. utility services, while utilities & insurgents pursue new business models 	<ul style="list-style-type: none"> • Explore “Total DSO” aggregation of DER wholesale market transactions • Consider optimal scope of regulated distribution monopoly with high DER

Who knows what today? What is needed for market DER?

Information Type	ISO	DO/DSO	ISO participating DER/DERP
DER/DERP bids to ISO market	X	Add ?	X
DER installed capacity		X	X
T system topology & conditions	X		X
D system topology & conditions		X	DO inform DER
DA & RT forecasts of load + non-ISO participating DER	Add	Add	
ISO DA market schedules	X	Add	X
ISO RT market dispatches	X	Add	X
T feasibility of ISO schedules & dispatches	Ensured by ISO optimization		Ensured by ISO optimization
D feasibility of ISO schedules & dispatches		DO assess & inform DER	DO inform DER
Revenue meter data	X		X
Generation/DER telemetry	X	X	
System telemetry	T system	D system	

The design of ISO-DSO coordination for high DER is enmeshed with design of the future DSO.

❖ Bookend A: Current Path or “Minimal DSO”

- DSO maintains current distribution utility role, with enhancements only as needed to ensure reliability with high DER volumes
- Large numbers of DER & DER aggregations participate in ISO market
- DER engage in “multiple-use applications” (MUA) providing services to end-use customers, DSO and wholesale market

❖ Bookend B: “Total DSO”

- DSO expands its role to include
 - DER aggregation for wholesale market participation
 - Optimizing local DER to provide transmission grid services
 - Balancing supply-demand locally
 - Manage DER variability to minimize impacts at T-D interface
 - Operation of distribution-level transactive markets
- DSO provides a single aggregated bid to ISO at each T-D interface
- Multi-use applications are simplified because DSO manages DER response to ISO dispatch

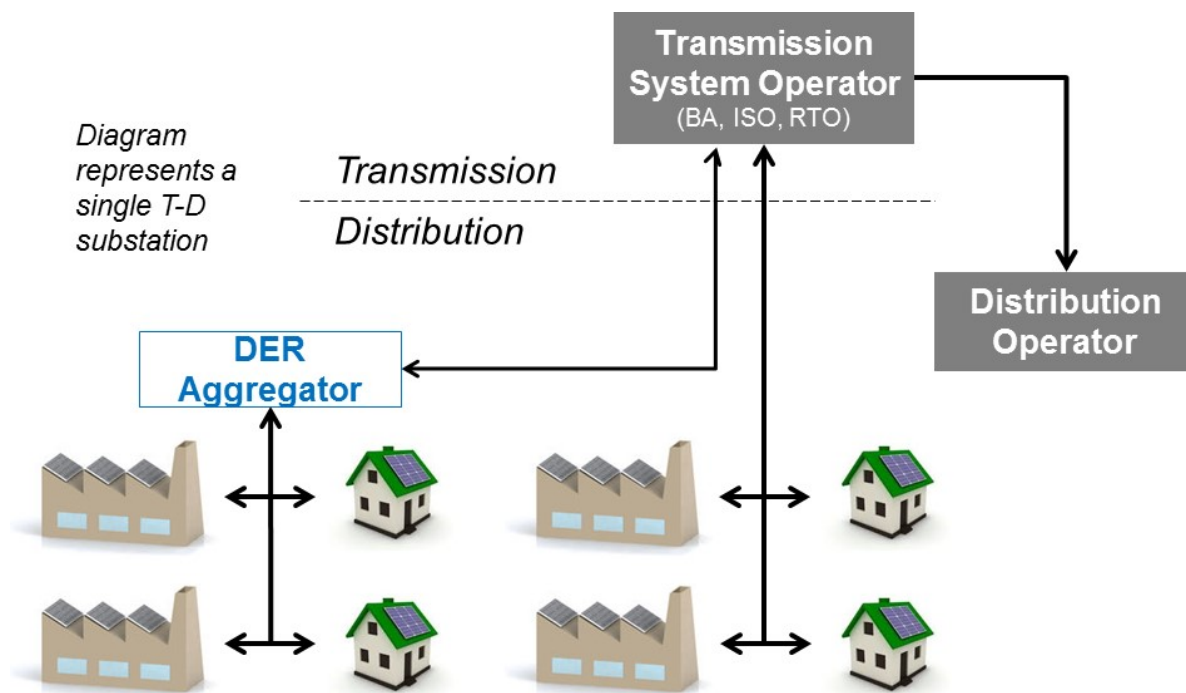
The choice of DSO model implicates several key power system design elements.

Design Element	Minimal DSO	Total DSO
Market structure	Central market optimization by ISO with large numbers of participating DER	DSO optimizes local markets at each T-D substation; ISO market sees a single virtual resource at each T-D interface
Distribution-level energy prices	Locational energy prices based on LMP plus distribution component (e.g., LMP +D)	Based on value of DER services in local market, including LMP for imports/exports
Resource/capacity adequacy	As today, based on system coincident peak plus load pocket & flexibility needs; opt-out allowed for micro-grids	Layered RA framework: DSO responsible for each T-D interface area; ISO responsible to meet net interchange at each interface
Grid reliability paradigm	Similar to today	Layered responsibilities; e.g., DSO takes load-based share of primary frequency response
Multiple-use applications of DER (MUA)	DER subject to both ISO and DSO instructions Rules must resolve dispatch priority, multiple payment, telemetry/metering issues	DER subject only to DSO instructions, as DSO manages DER response to ISO dispatches & ancillary services provision
Regulatory framework	Federal-state jurisdictional roles similar to today	Explore framework to enable states to regulate distribution-level markets
Comparable to existing model	Current distribution utility roles & responsibilities, enhanced for high DER	Total DSO is similar to a balancing authority

“Minimal DSO” retains current primary DO role – reliable operation & planning – for high DER & TE.

ISO directly integrates all DER for both transmission and distribution system operations. Requires ISO to incorporate distribution grid network model and have complete real-time distribution grid state information.

This approach is not advised due to complexity & scaling risks

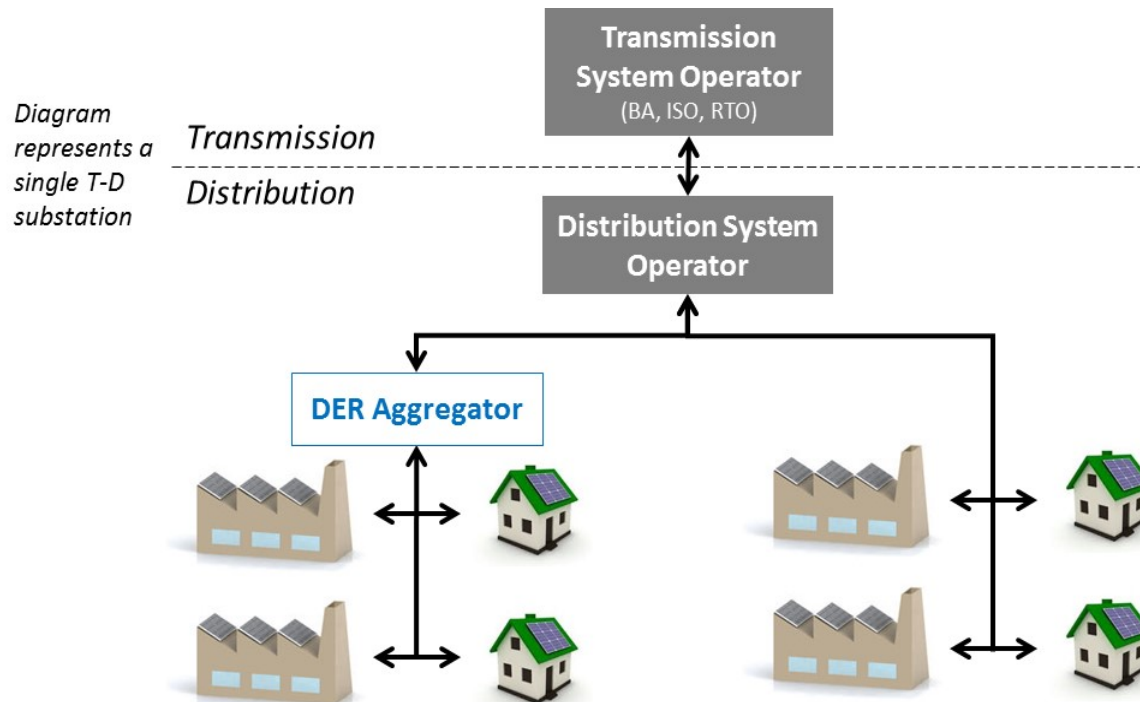


Source: De Martini & Kristov, Distribution Systems in a Highly Distributed Energy Resources Future, LBNL, 2015

“Total DSO” – similar to an ISO at distribution level – is the most robust & scalable model for high DER.

DSO directly integrates all DER for Local Distribution Area for each T-D Interface (e.g., LMP pricing node) and coordinates T-D interchange with TSO, so that ISO sees only a single resource at each T-D interface and does not need visibility to DER. DSO manages all intra-distribution area transactions, schedules and energy flows.

DSO coordinates a single aggregation of all DER at each T-D interface



Source: De Martini & Kristov, Distribution Systems in a Highly Distributed Energy Resources Future, LBNL, 2015

DER growth and distribution-level markets trigger other new policy and design questions.

- Open-access structure for distribution system operators (DSOs)
 - Non-discrimination in distribution services, resource interconnection, infrastructure investment, real-time re-dispatch as needed
 - Is an independent DSO needed? Or can today's utility DO be effectively firewalled into a regulated "wires & markets" operator and competitive affiliate offering retail services?
- Possible new boundary definition for federal-state jurisdiction
 - Could states regulate "sales for resale" that occur within a local transactive market without using transmission?
- Could reliability responsibilities be layered?
 - "Total DSO" aggregates all DER & customers below a T-D substation and submits a single virtual resource to ISO at the interface
 - ISO responsible for system reliability only to the T-D interface
 - DSO responsible from T-D interface to the customer meter
 - A micro-grid takes responsibility for its own reliability, and will island if grid supply is limited or interrupted

Grid architecture tools enable a whole-system approach to electric system transformation.

External context:

Ecosystem & resource constraints; global demographic & economic trends & conditions; technological advances & availability; geopolitics

Desired electric system qualities:

Reliable & safe operation; cyber/physical security; resilience to disruptive events; environmental sustainability; customer & community choice; affordability & access; financeability

Today's ISO & DO roles & responsibilities affecting T-D interfaces

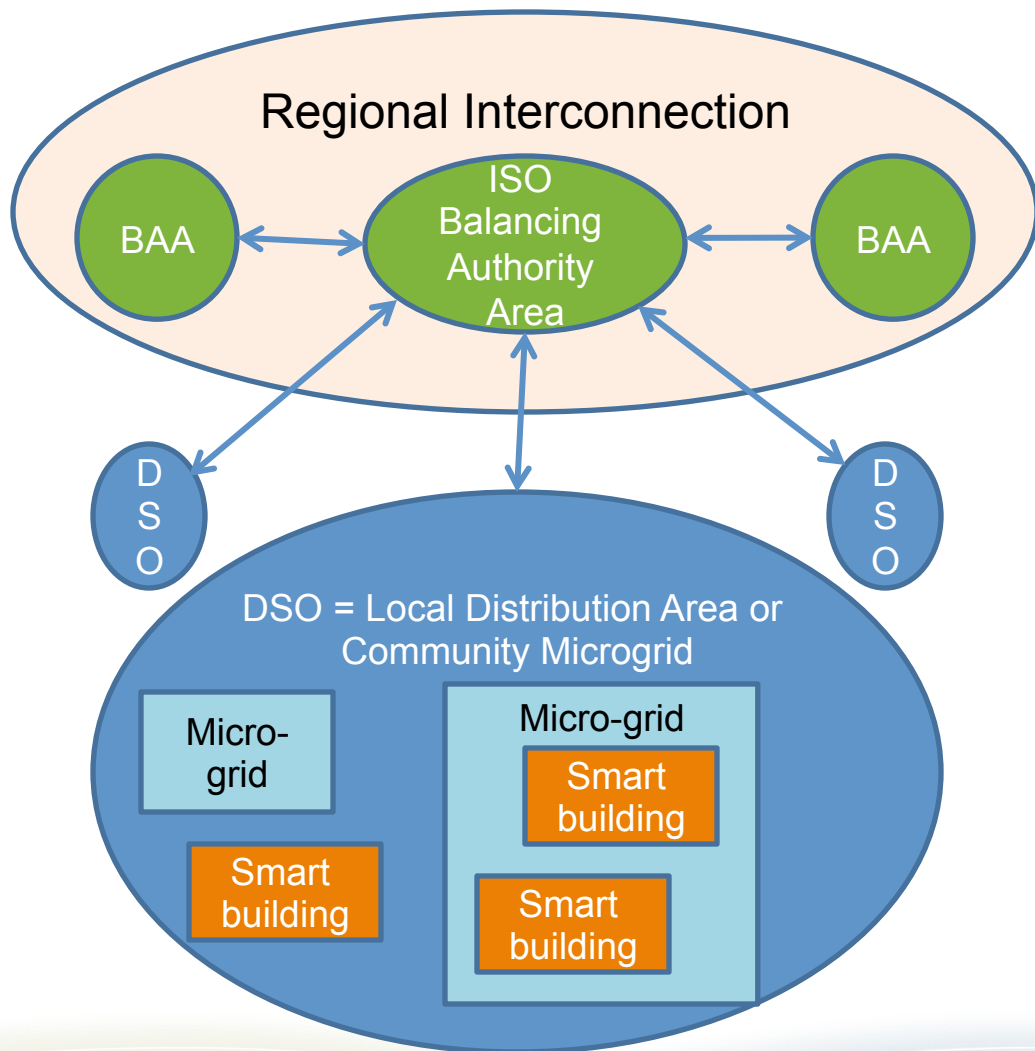
Transform into

New ISO-DSO T-D interface coordination framework for high DER

Policy context:

Regulatory framework; industry structure; markets & market designs; energy & environmental policies & mandates

The future grid may be a layered hierarchy of optimizing sub-systems.



- Each tier only needs to see interchange with next tier above & below, not the details inside other tiers
- ISO focuses on regional bulk system optimization while DSO coordinates DERs
- Layered control structure reduces complexity, allows scalability, and increases resilience & security
- Fractal structure mimics nature's design of complex organisms & ecosystems.

Thank you.

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Additional resources

- ❖ L. Kristov, P. De Martini, J. Taft (2016) “Two Visions of a Transactive Electric System” (IEEE Power & Energy Magazine, May-June 2016):
http://resnick.caltech.edu/docs/Two_Visions.pdf
- ❖ P. De Martini & L. Kristov (2015) “Distribution Systems in a High Distributed Energy Resources Future: Planning, Market Design, Operation and Oversight” (LBNL series on Future Electric Utility Regulation):
https://emp.lbl.gov/sites/all/files/FEUR_2%20distribution%20systems%2020151023.pdf
- ❖ L. Kristov (2015) “The future history of tomorrow’s energy network” (Public Utilities Fortnightly, May 2015):
<http://www.fortnightly.com/fortnightly/2015/05/future-history-tomorrows-energy-network?page=0%2C0&authkey=afacbc896edc40f5dd20b28daf63936dd95e38713e904992a60a99e937e19028>
- ❖ L. Kristov & P. De Martini (2014) “21st Century Electric Distribution System Operations”:
<http://smart.caltech.edu/papers/21stCElectricSystemOperations050714.pdf>
- ❖ J. Taft et al, Pacific Northwest National Laboratory, Grid Architecture site
<http://gridarchitecture.pnnl.gov>