T-D Operational Coordination

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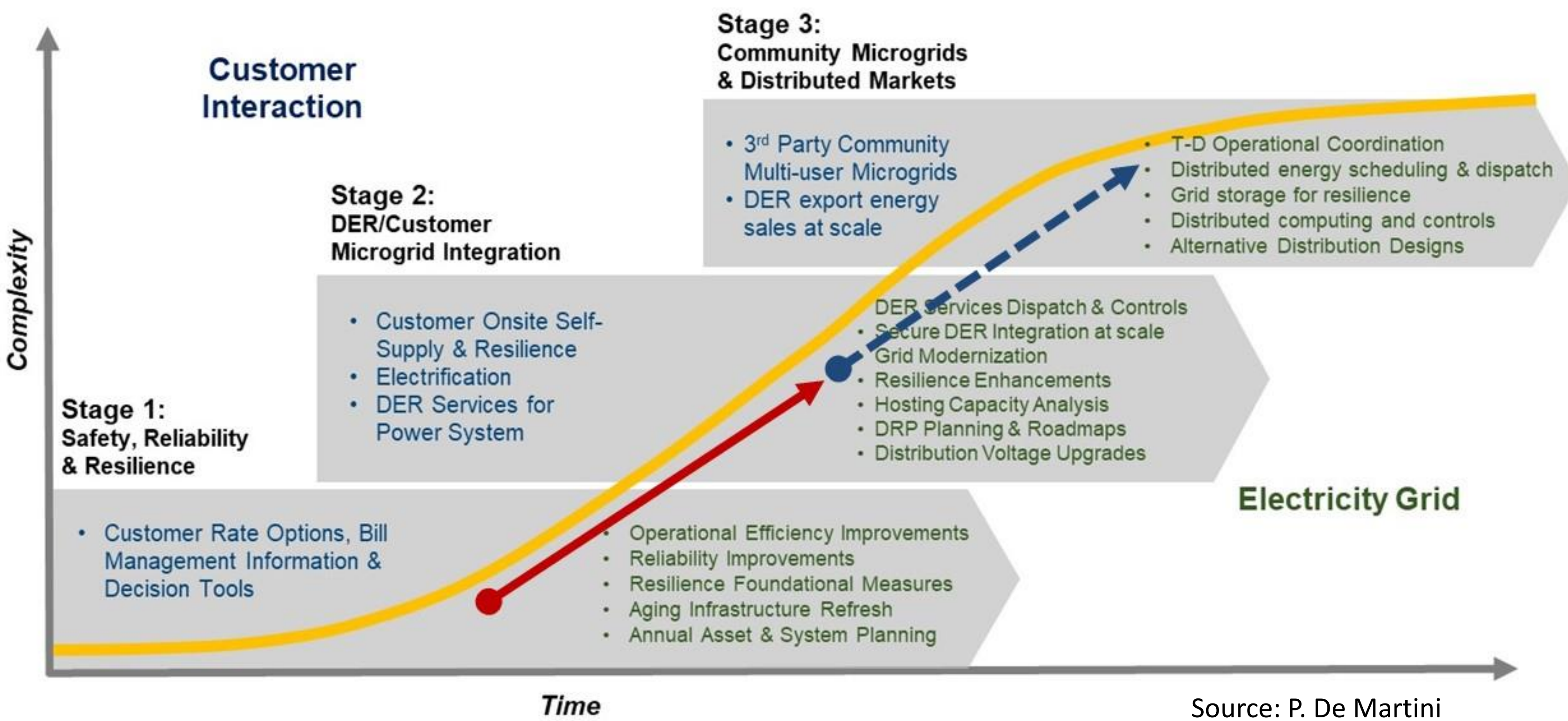
“The Future is Already Here, It Just Isn’t Evenly Distributed”

William Gibson

Customer Led Evolution

Many US States are or will be in Stage 2 by 2025 and several in Stage 3 by 2030



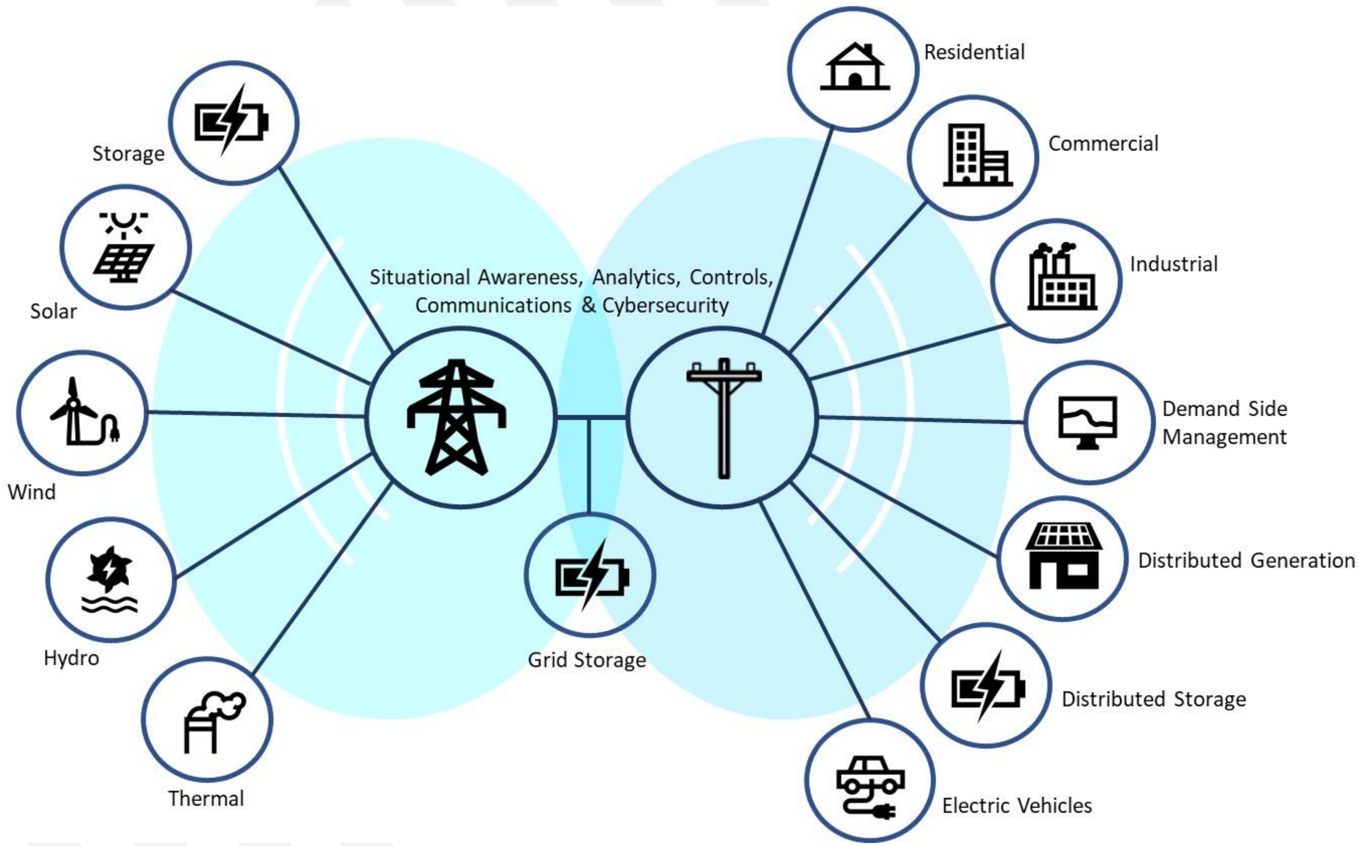
Source: P. De Martini

Over the past decade, the industry has focused on evolving from Stage 1 to Stage 2 – now looking forward to Stage 3

System Operational Coordination

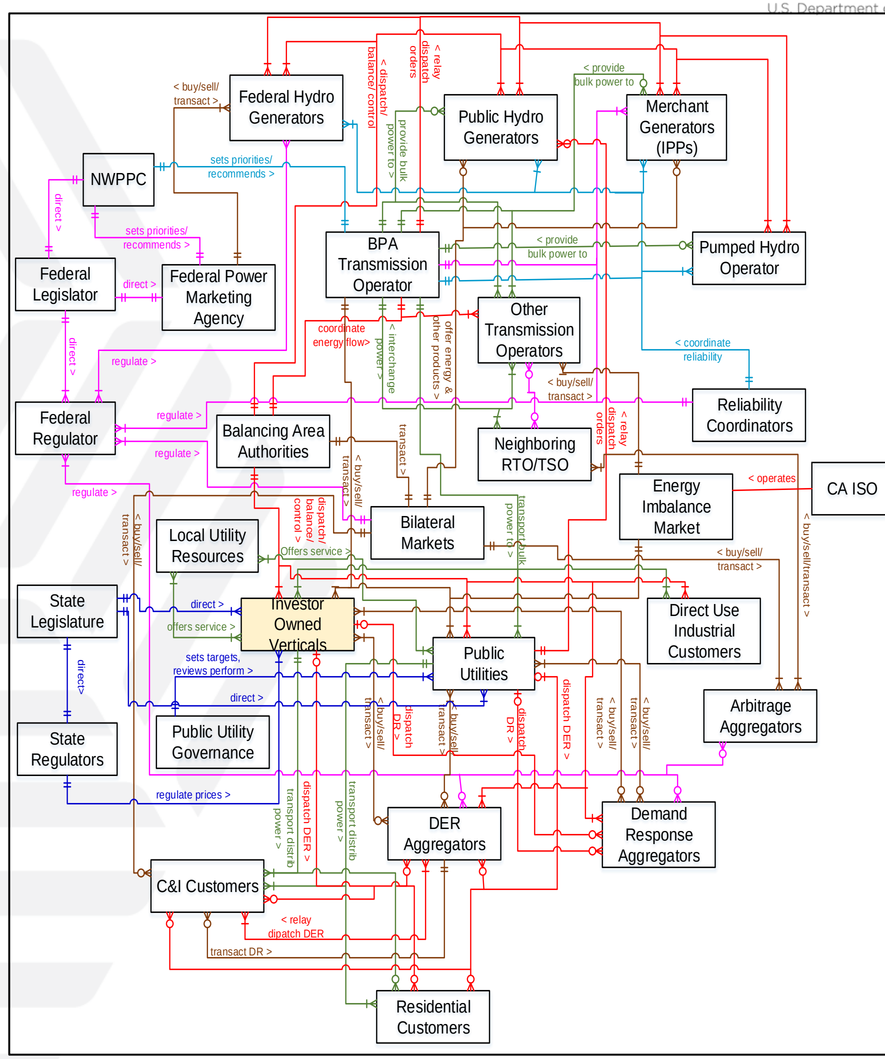
for a More Distributed System

An abundant low cost, clean energy future requires a re-evaluation of our legacy grid & operations - FERC 2222 is just one more step on our journey



Grid Has Complex Legacy Structure

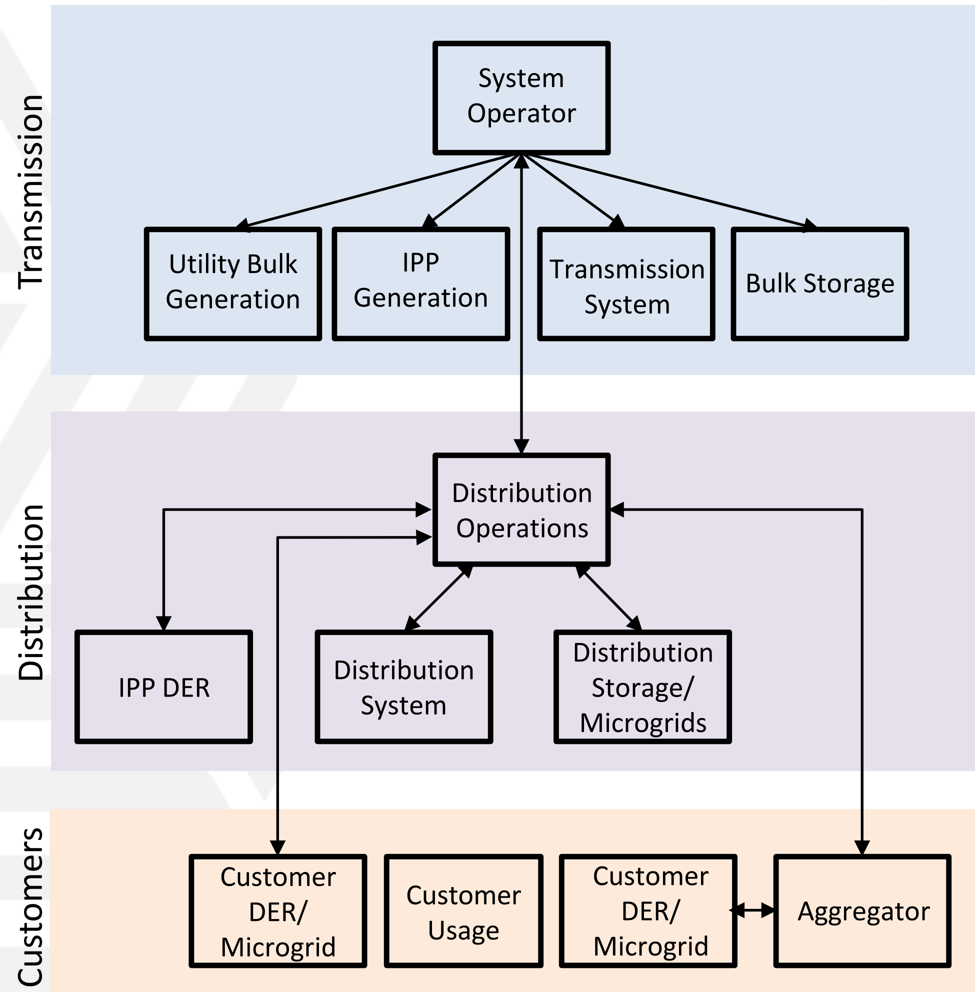
- Industry structure is the context within which modernization changes are being made
- Structure has been partly planned and partly grew organically
- Changing requirements and external forces are impacting existing structure



Source: J. Taft, PNNL

Coordination Framework Skeleton Diagram

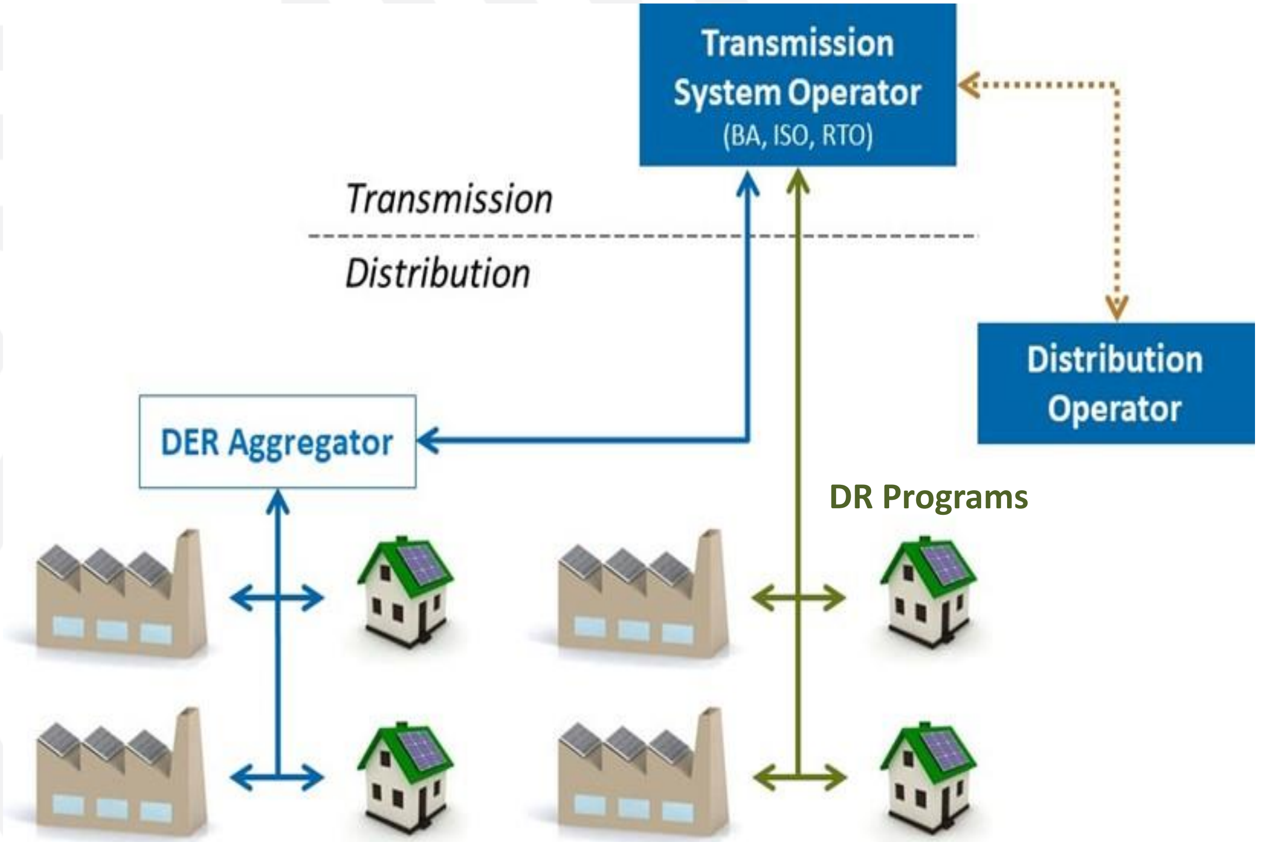
- Derives from Complex Industry Structure Diagram
- Focuses on key issues to address (e.g., architectural principles)
- Indicates flow of coordination
- Use layered decomposition model (i.e. Laminar Framework) as basis for the diagrams and analysis



Source: J. Taft & P. De Martini

Total TSO Conceptual Model

Centralized control of all DER resources across T&D – Requires TSO to also dispatch distribution NWAs and coordinate distribution operations

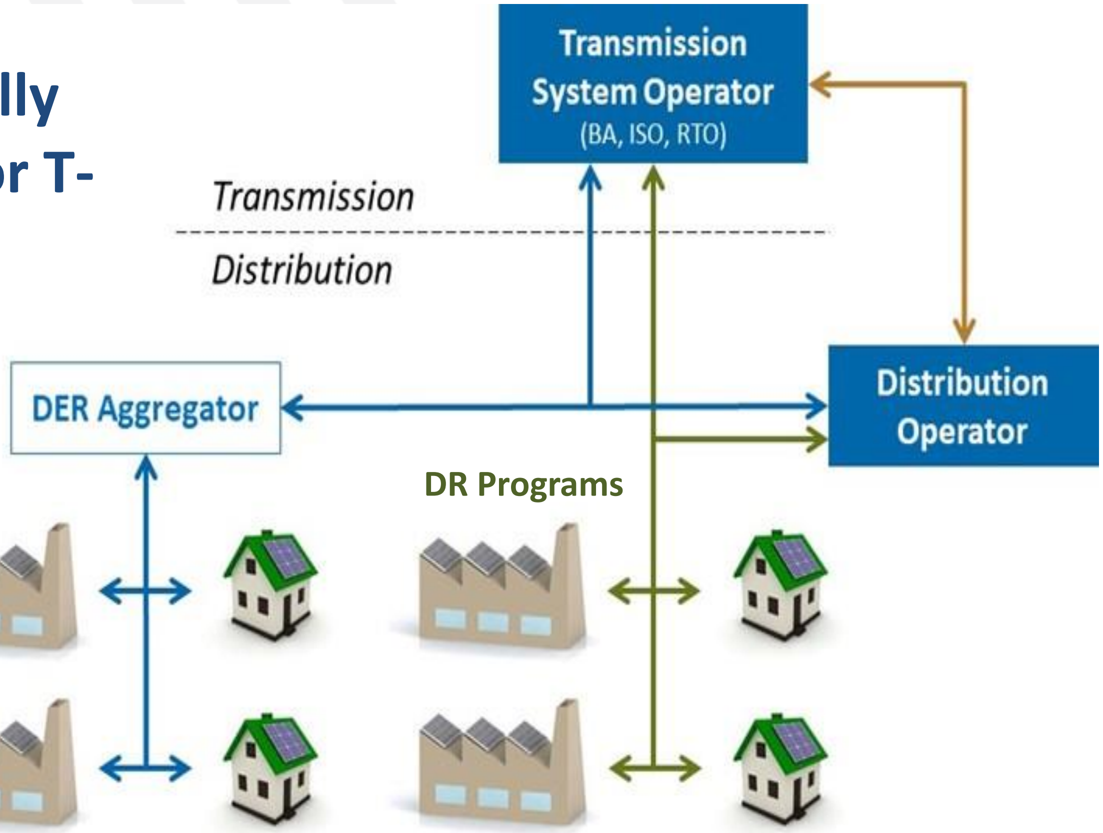


Source: P. De Martini

Hybrid DSO Conceptual Model

Shared responsibility for use of DER for Wholesale markets and Distribution NWAs as well as coordination of grid operations

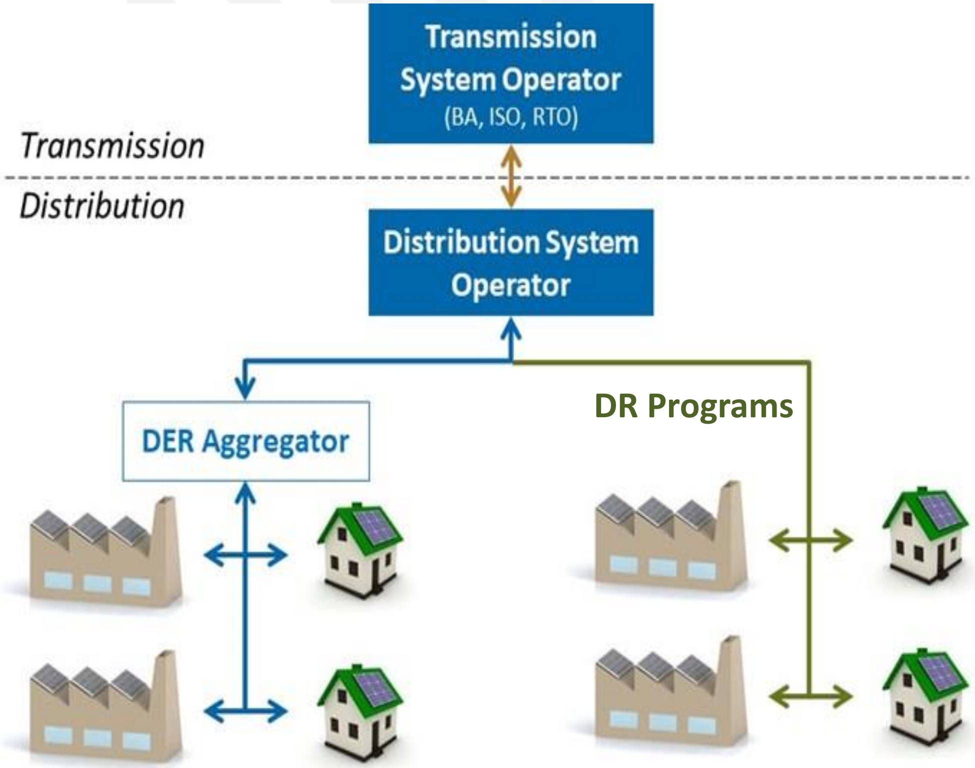
This model is typically the starting point for T-D Coordination, but unlikely to scale overtime



Source: P. De Martini

Total DSO Conceptual Model

Fully Layered Approach – DSO provides the single operational interface between DER and Wholesale Market Operator



Source: P. De Martini

Operational Coordination Models

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A spectrum of possible designs can be envisioned in terms of the complementary roles of DSO and TSO at the T-D interface.

Total TSO:	**Hybrid DSO**:	**Total DSO**:
TSO optimizes the entire power system into the distribution system, including dispatch coordination of all DER services and schedules	TSO optimizes the bulk power system – including dispatch of all wholesale DER services – but has no visibility into the distribution system	TSO optimizes the bulk power system. TSO sees a single aggregate or "virtual" resource at each T-D Interface managed by DSO
DSO responsible for reliable distribution network operations & providing distribution network visibility to TSO	DSO optimizes the distribution system – including dispatch of all distribution DER services & coordinates with TSO on all DER dispatch	DSO responsible for physical coordination & aggregation of all DER services into single resource at T-D Interface & wholesale market
Customer/Aggregator coordinates with TSO – no operational interface with DSO	Customer/Aggregator coordinates with both TSO and DSO	Customer/Aggregator coordinates with DSO – no operational interface with TSO

Source: De Martini & Kristov

Operational Coordination Functions

Distribution Functions	Dist. Owner	Total TSO	Hybrid DSO	Total DSO
1. Planning				
A. Scenario based, Probabilistic distribution engineering	DO	DO	DO	DO
B. DER Interconnection studies	DO	DO	DO	DO
C. DER Hosting capacity analysis	DO	DO	DO	DO
D. DER Locational value analysis	--	TSO	DSO	DSO
2. Operations				
A. Design-build and ownership of distribution grid	DO	DO	DO	DO
B. Switching, outage restoration & distribution mtce.	DO	DO	DO	DO
C. Physical coordination of DER schedules	--	DO/TSO	DSO/TSO	DSO
D. Real-time Coordination with ISO at T-D interface	--	DO/TSO	DSO	DSO
3. Market				
A. Sourcing distribution grid services	DO	TSO	DSO	DSO
B. Optimally dispatch DER provided distribution grid services	--	TSO	DSO	DSO
B. Aggregation of DER for wholesale market participation	--	TSO	Aggregators	DSO
C. Creation & operation of distribution level energy markets; transactions among DER	--	TSO	Stage 3 TSO/Other	DSO
D. Clearing and settlements for inter-DER transactions	--	TSO	Stage 3 TSO/Other	DSO
E. Market facilitation services	--	TSO	Stage 3 Other	DSO

Source: De Martini & Kristov

Architectural Principles

(Subset of architectural principles for TSO-DSO Coordination)

Principle	Description
Observability	Function related to operational visibility of the distribution network and integrated DER. Sufficient sensing and data collection can help to assemble an adequate view of system behavior for control and grid management purposes, thus providing desirable snapshots of grid state. The data can also be utilized to validate planning models. Observability needs of DSO and TSO depend on how the coordination framework is specified.
Scalability	Ability of system's processes and technology design to work well for very large quantities of DER resources. Coordination architecture can enhance or detract from this desired capability.
Cyber security vulnerability	While this topic has many dimensions, the principle here is to reduce cyber vulnerability through architectural structure. Structure can expose bulk energy systems to more or less vulnerability depending on data flow structure, which depends on coordination framework. To be minimized.
Layered decomposition	Layered decomposition solves large-scale optimization problems by decomposing the problem multiple times into sub-problems that work in combination to solve the original problem. Used here as the basis for comparing grid architectures.
Tier bypassing	Creation of information flow or instruction/dispatch/control paths that skip around a tier of the power system hierarchy, thus opening the possibility for creating operational problems. To be avoided.
Hidden coupling	Two or more controls with partial views of grid state operating separately according to individual goals and constraints; such as simultaneous, but conflicting signals DER from both the DSO and TSO. To be avoided.
Latency cascading	Creation of potentially excessive latencies in information flows due to the cascading of systems and organizations through which the data must flow serially. To be minimized.

Source: J. Taft, PNNL

Operational Coordination Architecture Methodology (OCAM)

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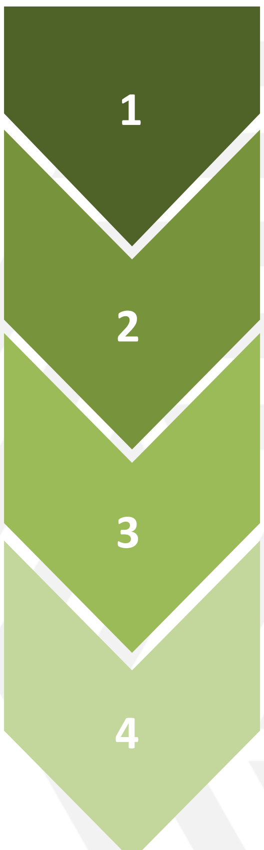

1. Identify Objectives & Capabilities
2. Document Existing/Emerging Structure
3. Develop Alternative Coordination Structures
4. Evaluate Coordination Alternatives:
    a. Operational Effectiveness/Risks
    b. Implementation Requirements & Costs

1. Identify Objectives, Capabilities & Constraints

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- ► Identify state & federal objectives, policy and regulations driving industry structural changes
- ► Identify scale and timing factors
- ► Identify new capabilities needed to address emergent requirements identified from structural changes
- ► Identify any institutional and practical constraints

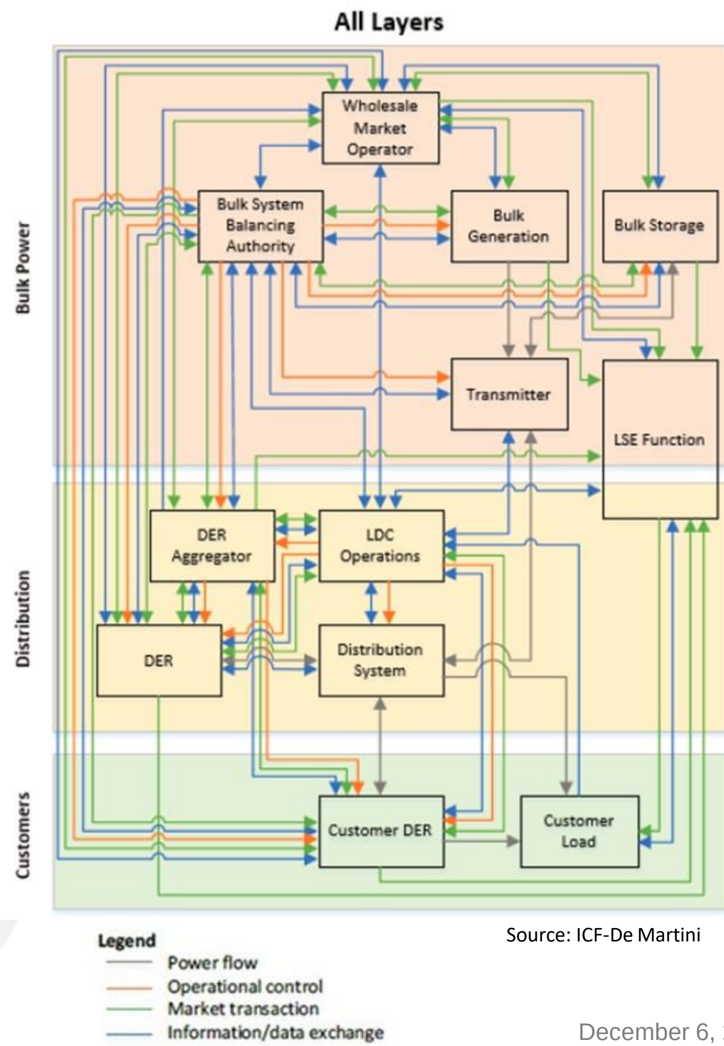
Capabilities
Planning
A. Scenario based, probabilistic distribution engineering analysis
B. Integrated T&D Planning
Operations
A. DER Interconnection & Grid Codes
B. Distribution Operational Engineering
C. Physical Coordination of DER Schedules
D. Distribution State Estimation
E. Operational Coordination at T-D interface
Markets
A. Sourcing Distribution Grid Services
B. Optimally Dispatch Distribution Grid Services
C. Aggregation of DER for Wholesale Market Participation
D. Operation of Distribution Level Energy Transactions
E. Clearing and Settlement for Distribution Level Transactions
F. Distribution Level Market Facilitation Services

Example

Source: Adapted from De Martini – Kristov, LBNL

2. Document Existing/Emerging Structure

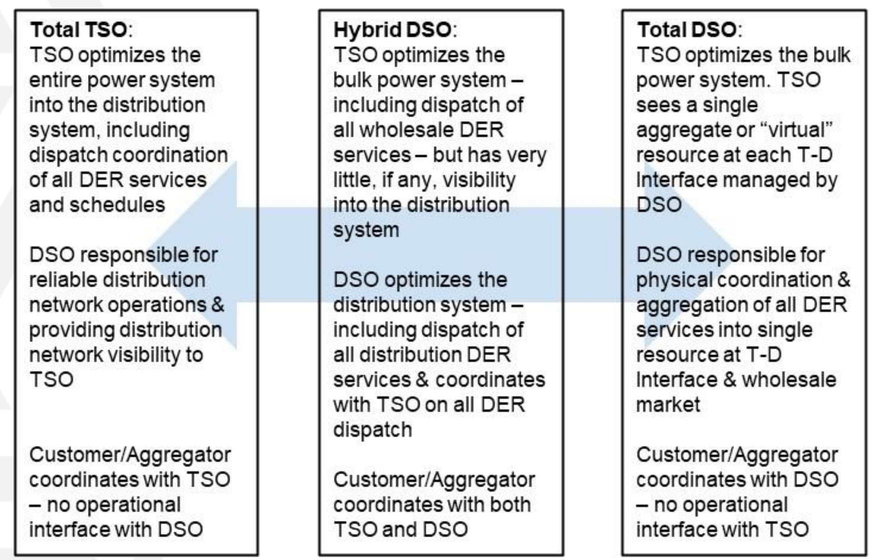
- ► Important to identify the current or emerging industry structure
- ► Structural diagram identifies the interrelationship of each of the principal entities as well as the roles and responsibilities
- ► Example shown includes power flow, operational control, market transactions and information/data exchange layers
- ► Additional layers can include regulatory and market oversight



Source: ICF-De Martini

3. Develop Alternative Coordination Structures

- Develop alternative coordination structure thru stakeholder engagement
- Alternatives should address the objectives driving the needed changes, grid architectural principles and any practical constraints
- Typically more than one alternative is developed given the practical/political trade-offs in relation to ideal structures that may be required



4. Evaluate Coordination Alternatives

	Considerations	Description
Effectiveness	**Observability**	Function related to operational visibility of the distribution network and integrated DER. Observability needs of DSO and TSO depend on how the coordination framework is specified.
	Scalability	Ability of system's processes and technology design to work well for very large quantities of DER resources. Coordination architecture can enhance or detract from this desired capability.
	Cyber security vulnerability	Reduce cyber vulnerability through architectural structure. Structure can expose grid systems to more or less vulnerability depending on data flow structure, which depends on coordination framework.
	Layered Optimization	Large-scale optimization problems are decomposed into multiple sub-problems at discrete layers of the electric system within a coordinated structure.
Risks	**Tier bypassing**	Creation of information flow or instruction/dispatch/control paths that skip around a tier of the power system hierarchy, thus opening the possibility for creating operational problems. To be avoided.
	Hidden coupling	Two or more controls with partial views of grid state operating separately according to individual goals and constraints; such as simultaneous, but conflicting signals DER from Customer, DSO and TSO. To be avoided.
	Latency cascading	Creation of potentially excessive latencies in information flows due to the cascading of systems and organizations through which the data must flow serially. To be minimized.

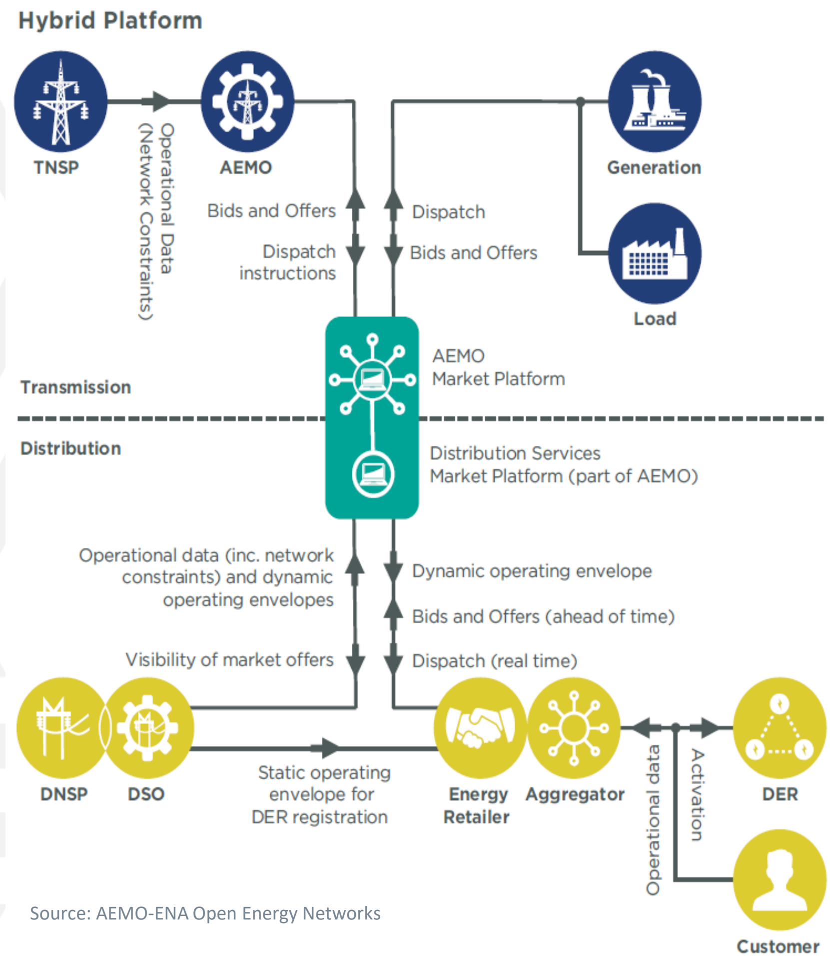
Source: J. Taft, Pacific Northwest National Laboratory

AEMO Total TSO Option Example

This Specific Approach is Not Recommended

Example Grid Architectural Analysis:
This is a Total TSO based model that is proposed to **only use market mechanisms** for T-D coordination and distribution operational services control. Note there are **no operational or physical coordination links between the AEMO (TO) and the DO/DNSP** only market visibility.

This model **exhibits problematic tier bypassing** due to the path from DER to aggregator/retailer to TO that bypasses the DO. In addition, the potential for **hidden coupling exists, with some aggregators and LSEs and the TO market all have dispatch potential with DERs** unless some coordination mechanism is worked out. The presence of the DER aggregator-to-TO connection also presents a **moderate cyber vulnerability** to the bulk energy system.



Source: AEMO-ENA Open Energy Networks

References

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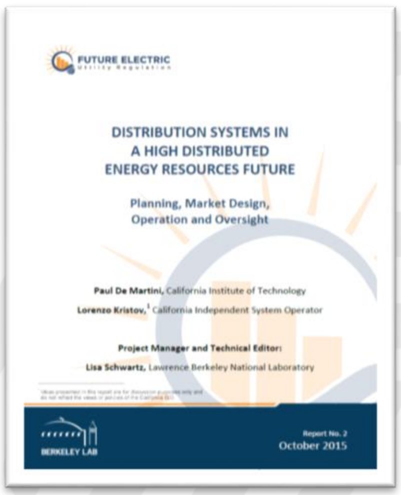
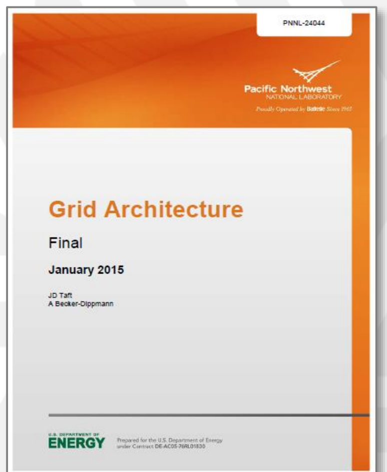
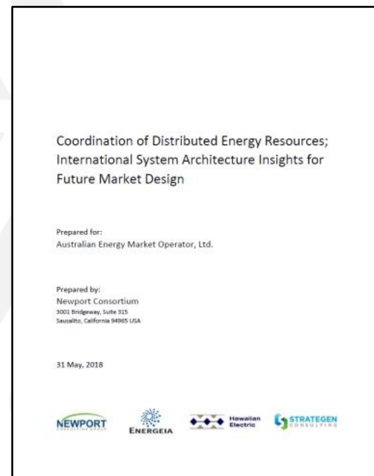
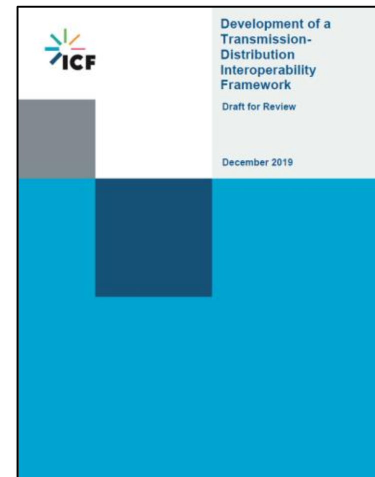
T-D Operational Coordination	Grid Architecture	AEMO Intl Survey	IESO Evaluation
			
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“Entities should not be multiplied without necessity“

Occam’s Razor

Seek the simplest structural options as complexity creates fragility