Operational Coordination

January 29, 2020

Paul De Martini
Executive Director, Pacific Energy Institute
Visiting Scholar, Caltech

pacific energy INSTITUTE

Caltech
Resnick Institute

Architectural Considerations

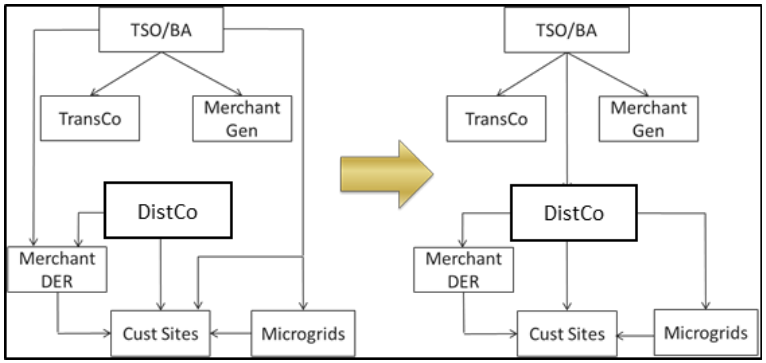
(for T-D Operational Coordination)

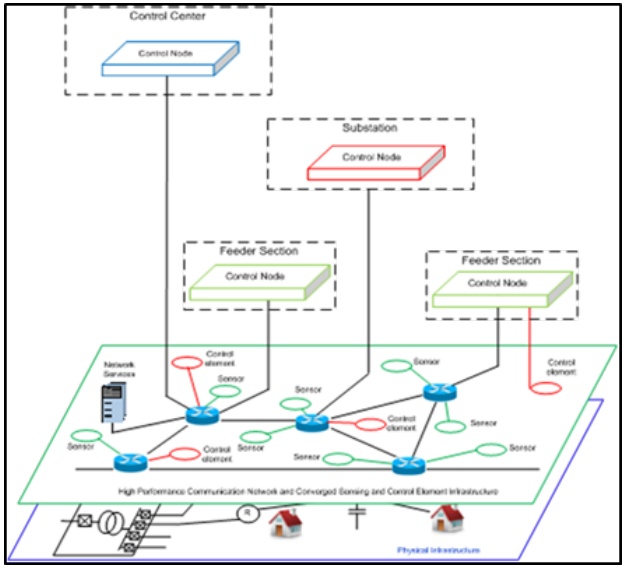
	Considerations	Description
Desirable	**Observability**	Function related to operational visibility of the distribution network and integrated DER. Observability needs of DSO and TSO depend on how the coordination framework is specified.
	Scalability	Ability of system's processes and technology design 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.
Undesirable	**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

Some Key Architectural Issues

- Role Assignments
  - Responsibility/role matching
  - Feedback loops
    - Information flows and latencies
  - Competing or conflicting objectives
    - Local selfish optimization vs. global coordination
- Assignments cannot just be arbitrary
  - Based on solid architectural principles
  - Explain why, not just what

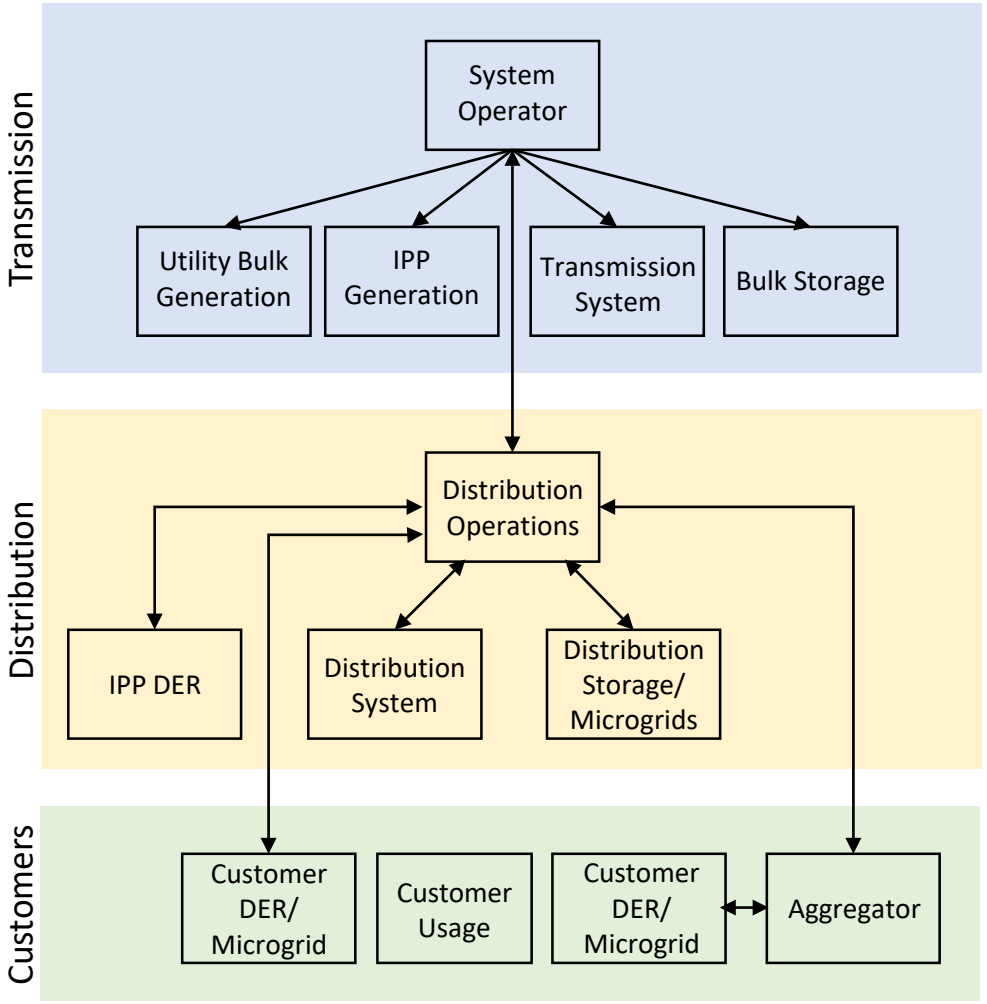




Source: J. Taft, PNNL

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

UK Coordination Models

Current & Future Models Under Discussion

- UK Open Networks initiative evaluating alternative TSO-DSO Coordination Models
- 5 Future Models have been identified and under evaluation
  http://www.energynetworks.org/electricity/futures/open-networks-project/

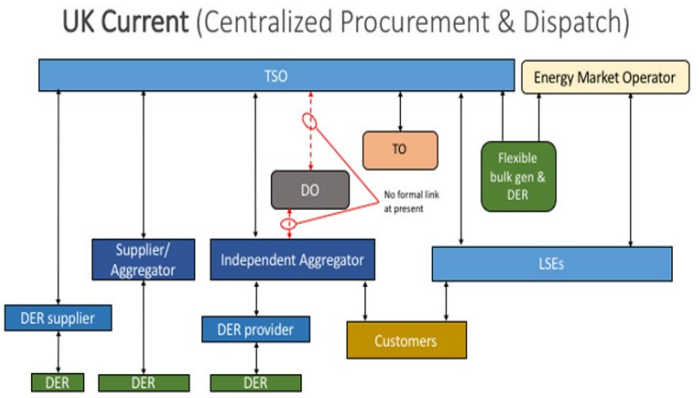
Example Grid Architectural Analysis:

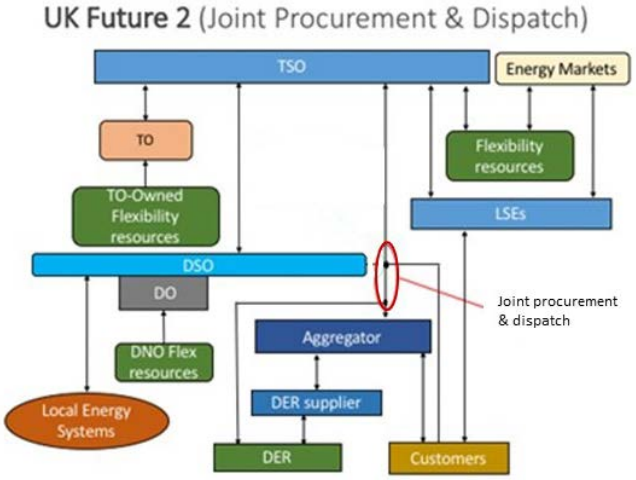
UK Option 2, the responsibility for DER coordination is shared by the DSO and TSO, leading to a more complicated arrangement involving these parties and the aggregators, although the sharing mechanism is not clear.

This model is somewhat similar to the Total DSO model, but the sharing arrangement results in a blending of roles that will require extra coordination to perform.

Option 2 partially **degrades the layered decomposition** structure and allows for **some tier bypassing**, although the proposed function-sharing ("joint procurement and activation") may prevent that from being an issue. This structure **increases the coupling** between the TSO and DSO (not hidden in this case), since the DSO cannot manage the DER in its service area alone while interfacing to the TSO in a modular fashion.

The joint arrangement results in **data flow complexity** involving the DSO, the TSO, the aggregators, the customers, and DER. This is a result of the structure shown in the red oval which comes about due to the definition of **joint roles instead of clean separation of functions**.





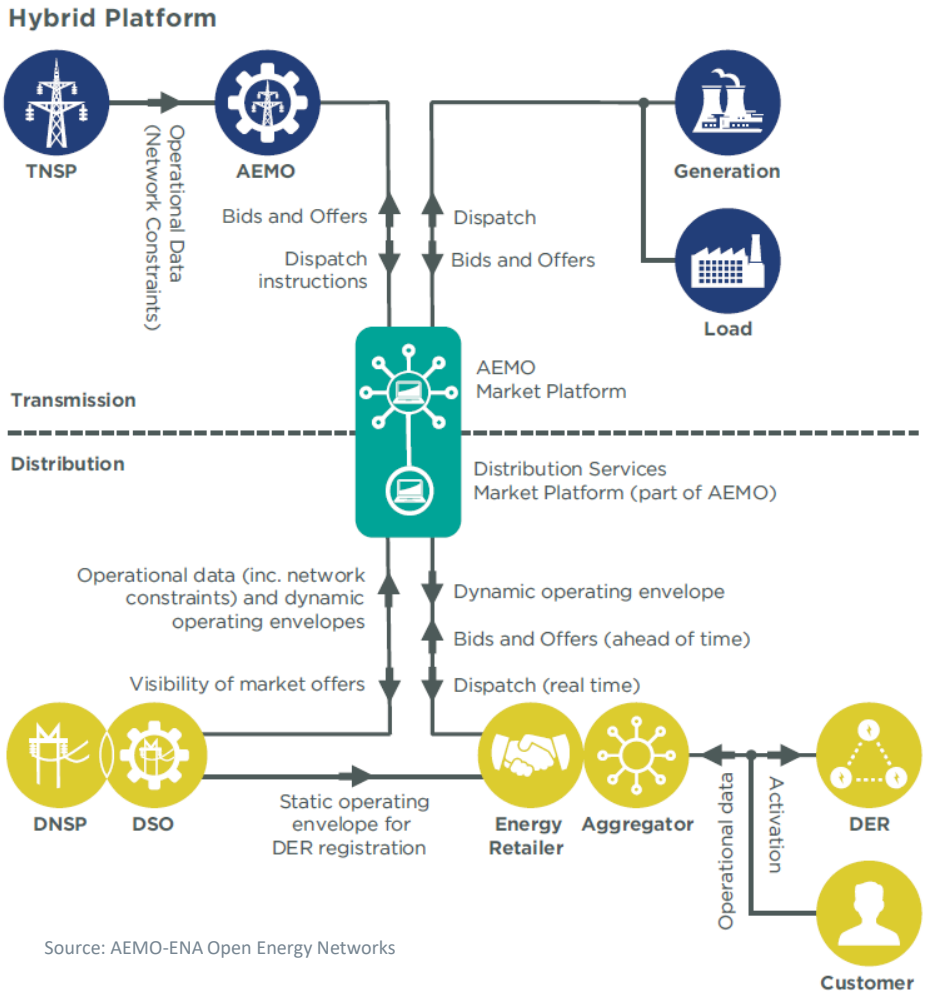
Source: J. Taft, L. Kristov & P. De Martini

Caltech
Resnick Institute

AEMO Coordination Model Example

Example Grid Architectural Analysis:
This is a TSO centric 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 (TSO) and the DSO/DNSP** only market visibility.

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



Source: AEMO-ENA Open Energy Networks

NY Coordination Models

Current & Future Models Under Discussion

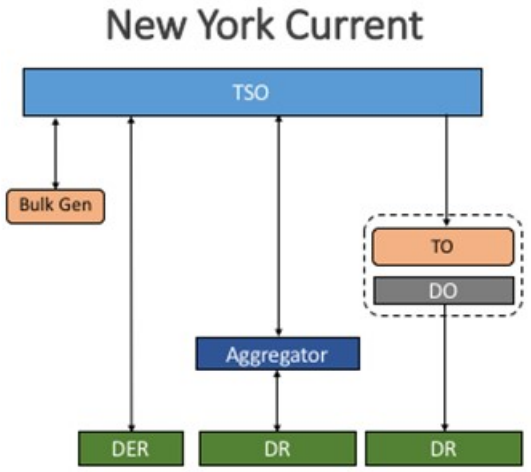
Example Grid Architectural Analysis:

Future 2, the removal of the link between the aggregator and the TSO creates **some of the layered decomposition** structure by **eliminating one source of tier bypassing**, but the presence of a link from DER to the TSO **still allows for tier bypassing, hidden coupling, scalability issues, and cyber vulnerability** at the TSO level.

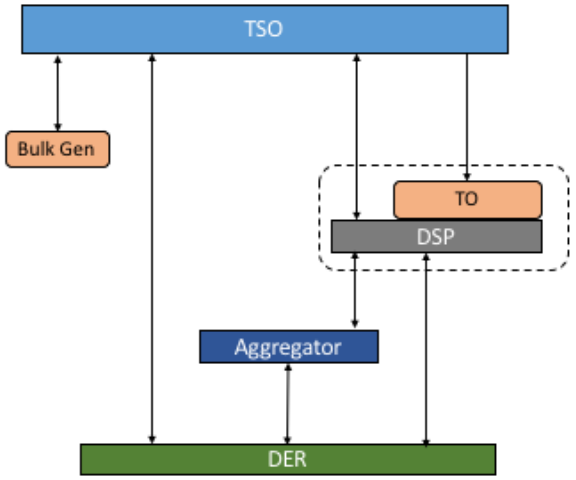
Future 2, the DSP is potentially somewhat better able to manage the DER, and if coordination between TSO and DSP is well organized, the **tier bypassing problem may be mitigated**.

If some **DER are bidding into the wholesale markets and some into a DSP market**, for example, then the **potential for mis-coordination exists**.

The potential **ability of aggregators to participate at the TSO level is eliminated** in this model that **reduces tier bypassing**. However, it **does not eliminate tier bypassing** as some DERs can still bypass. The **hidden coupling problem remains** but likely at a low level.



NYISO Proposed Future 2



Source: J. Taft, P. De Martini & L. Kristov

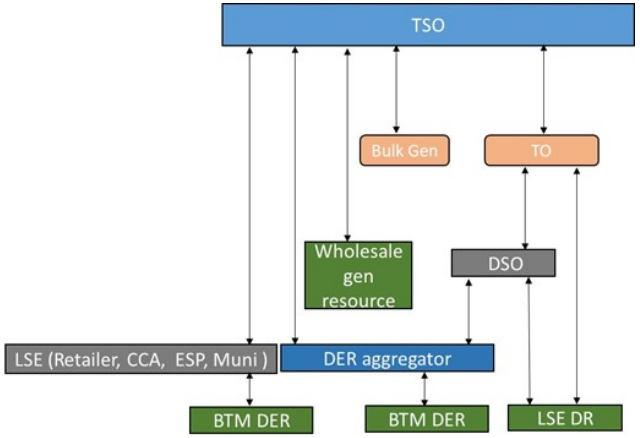
CA Coordination Models

Prior & Future Models

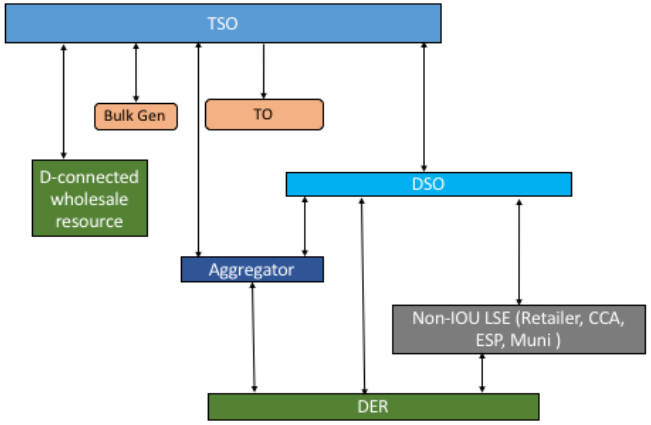
Example Grid Architectural Analysis:
The previous California structure reflects DER services provided directly to the TSO as well as the existing demand response (DR) programs that distribution utilities operate for the benefit of wholesale market operations. The resulting complexity involves a large number of entities and a somewhat **ad hoc coordination structure**. Note there are **no coordination links between the CAISO (TSO) and the DSO**.

A future **Hybrid DSO based model**, may be politically feasible in near-term. A hybrid model will **continue to exhibit tier bypassing** due to the path from DER to aggregator to TSO that bypasses the DSO. In addition, the potential for **hidden coupling exists, with some aggregators, LSEs and the DSO all connecting to DERs** unless some coordination mechanism is worked out. The presence of the direct aggregator-to-TSO connection also presents a moderate cyber vulnerability to the bulk energy system.

California Prior



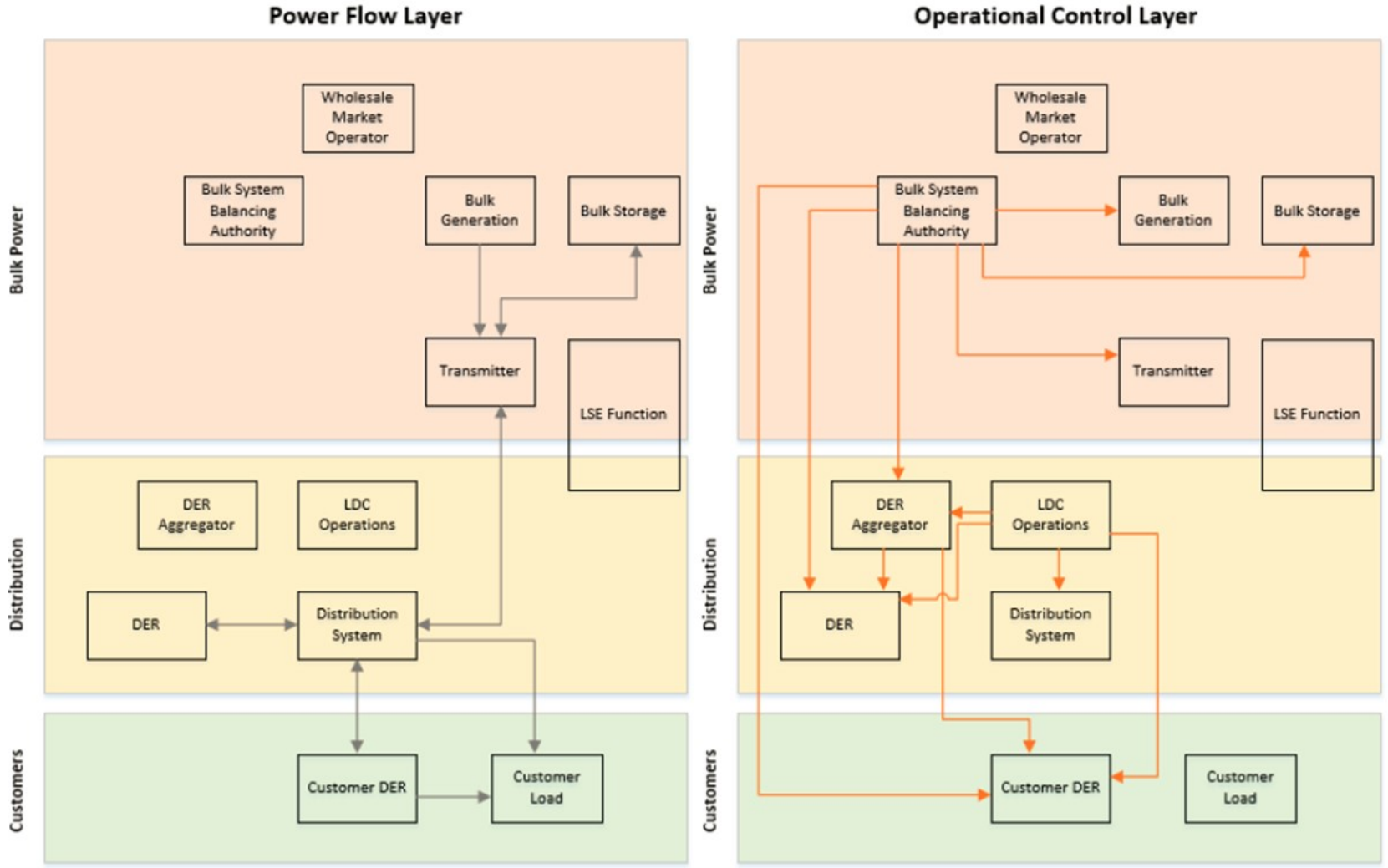
California Future



Source: J. Taft, P. De Martini & L. Kristov

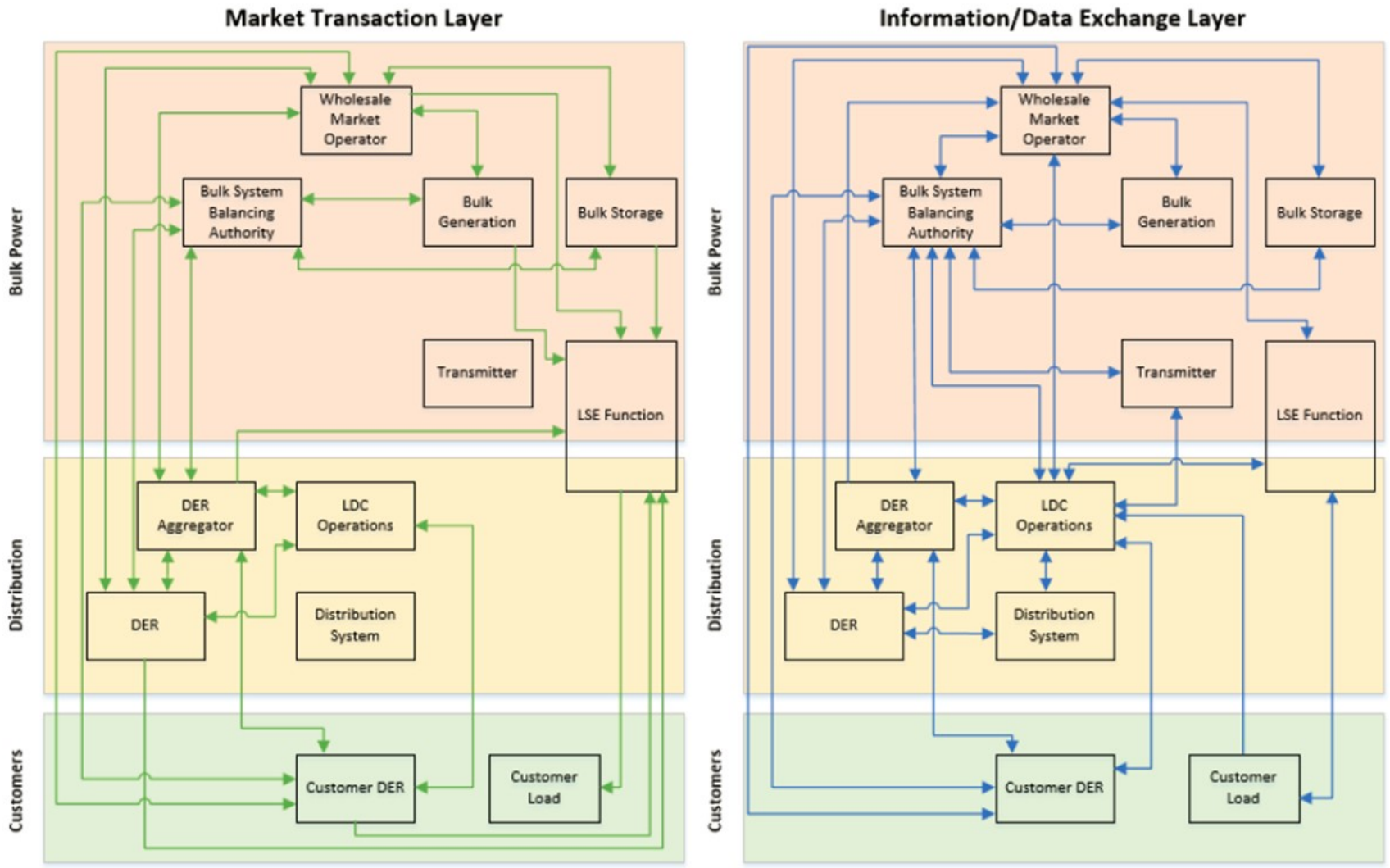
IESO Example

Figure 2: Ontario emerging industry structure diagram



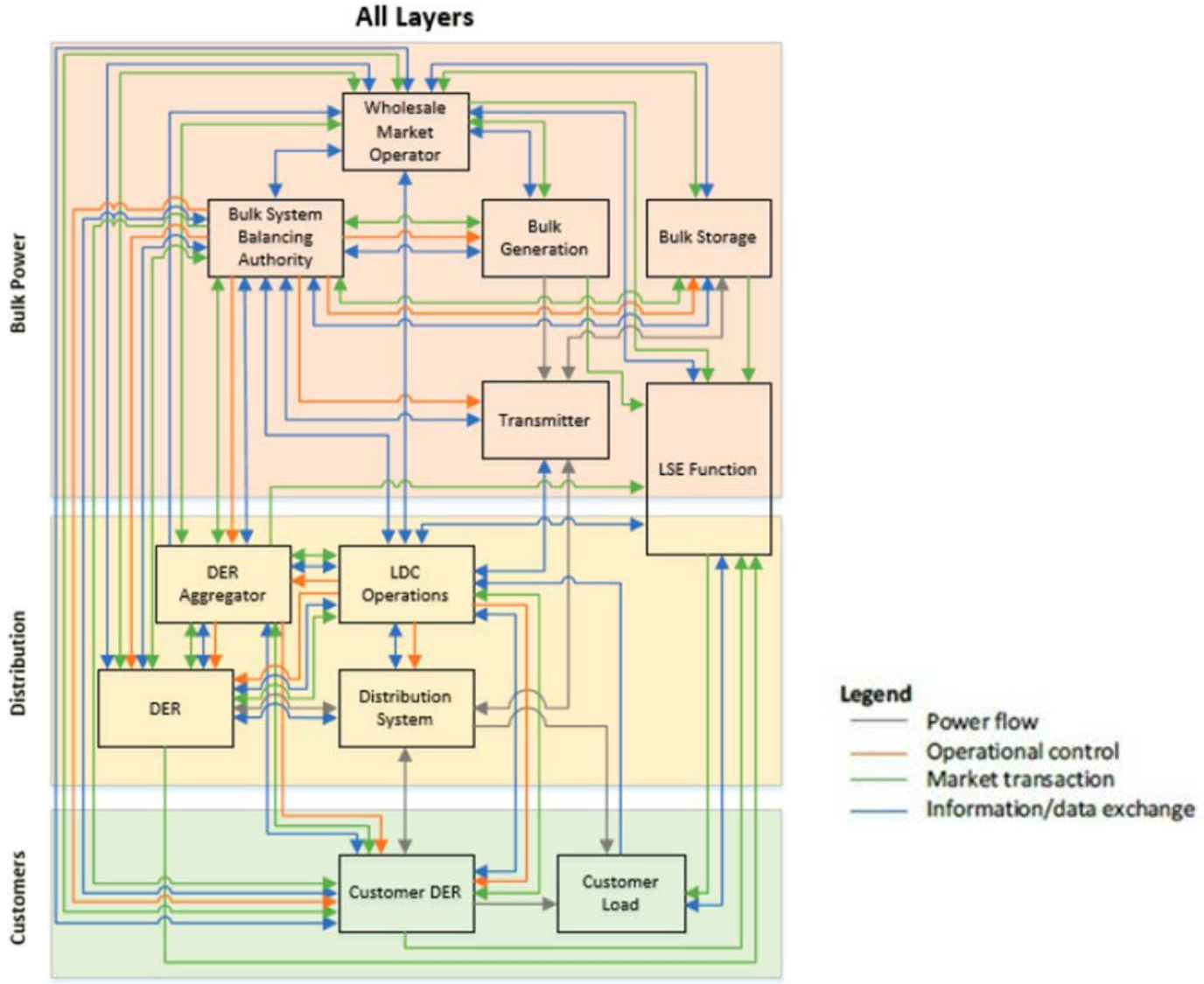
Source: ICF-De Martini

IESO Example



Source: ICF-De Martini

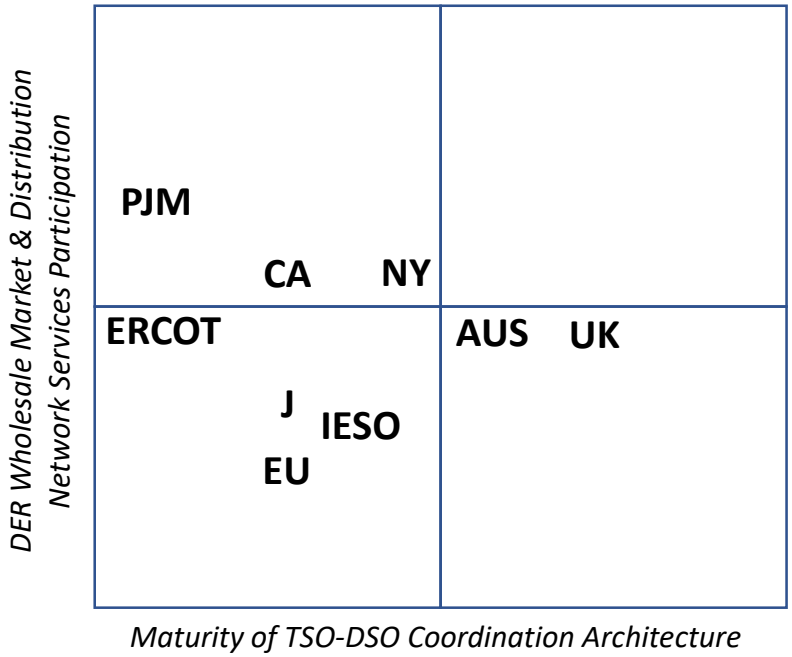
IESO Example



Source: ICF-De Martini

2018 International TSO-DSO Comparative Assessment

Primary and secondary research supporting comparative assessment of TSO-DSO development efforts in 8 regions/countries



UK & AUS have the most sophisticated approaches and analysis conducted to-date. But, are hampered by a strong institutional and stakeholder bias towards real-time centralized markets despite the significant operational issues.

Takeaways

- Future models involve two schools of thought regarding coordination structure:
  - Centralized approach where the TSO performs all coordination
  - Layered approaches where a DSO has a significant role in coordination.
- Current proposed coordination models are using Hybrid approaches for all locations reviewed
  - Exhibit considerable distribution operator bypassing, with the attendant issues of hidden coupling and cyber vulnerability.
  - Hybrid approaches are not sustainable at scale

Thank you