Transmission/Distribution Operational Coordination

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System Architecture & Grid Architecture

**Architecture**
- An abstract depiction of a system, consisting of black box components, structure, and externally visible characteristics

**Purposes:**
- Identify legacy constraints
- Remove barriers and refine essential limits
- Help manage complexity (and therefore risk)
- Support early stage modernization processes
- Identify gaps in structure, technology
- Assist communication among stakeholders
- Define platforms
- Inform interfaces and interoperability

**Grid Architecture**: The application of system architecture, network theory, and control theory to the electric power grid.

A grid architecture is the highest-level description of the complete grid and is a key tool to help understand and define the many complex interactions that exist in present and future grids.
Definition: The Coordination Problem

• Grid coordination is the systematic operational alignment of utility and non-utility assets to provide electricity delivery.

• Many of these resources are not owned by the utility and often cannot be controlled directly.

The 20th Century electric grid was not intended to handle these issues.

• This has led to the organic development of structural problems with coordination.
Operational Problems to Avoid

Hidden Coupling

- Prices to Devices
- Utilities and DER Operators
- Transmission/Distribution Bypass
Structural Traps to Avoid

- Tier Bypassing
- Coordination Gapping

Diagram:
- TSO/BA
- TransCo
- Merchant Gen
- DistCo
- Merchant DER
- Cust Sites
- Microgrids

Notes:
- Tier bypassing
- Coordination gap
Not So Simple to Recognize in Real Situations
Layered Decomposition Provides A Coordination Building Block: Laminar Coordination

- Multi-layer multi-scale structure
- Core repeating building block: coordination domain
- Allows mixed coordination signal models:
  - Allocations (control)
  - Prices (market-like methods)
- Scalable inter-layer interaction
- Proportional buildability
The Building Block Can Be Used At Any Scale
Adjusting Coordination Structure to Laminar Form

- TSO/BA
  - TransCo
    - Merchant Gen
  - DistCo
    - Merchant DER
    - Cust Sites
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- TSO/BA
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Structure Informs Roles & Responsibilities, Interfaces

New Interface

LMP Node

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

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<tr>
<th>Type</th>
<th>Description</th>
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<td><strong>Total TSO:</strong></td>
<td>TSO optimizes the entire power system into the distribution system, including dispatch coordination of all DER services and schedules. DSO responsible for reliable distribution network operations &amp; providing distribution network visibility to TSO. Customer/Aggregator coordinates with TSO – no operational interface with DSO.</td>
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<td><strong>Hybrid DSO:</strong></td>
<td>TSO optimizes the bulk power system – including dispatch of all wholesale DER services – but has no visibility into the distribution system. DSO optimizes the distribution system – including dispatch of all distribution DER services &amp; coordinates with TSO on all DER dispatch. Customer/Aggregator coordinates with both TSO and DSO.</td>
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<td><strong>Total DSO:</strong></td>
<td>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 physical coordination &amp; aggregation of all DER services into single resource at T-D Interface &amp; wholesale market. Customer/Aggregator coordinates with DSO – no operational interface with TSO.</td>
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Centralized control of all DER resources across T&D – Requires TSO to also dispatch distribution NWAs and coordinate distribution operations
Shared responsibility for use of DER for the wholesale markets and Distribution NWAs as well as coordination of grid operations
Fully Layered Approach – DSO provides the single operational interface between DER and Wholesale Market Operator
Operational Coordination Architecture Model (OCAM)

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
# Evaluating Coordination Alternatives

## Operational Effectiveness/Risks

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<th>Considerations</th>
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<td><strong>Effectiveness</strong></td>
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<tr>
<td>Observability</td>
<td>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.</td>
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<td>Scalability</td>
<td>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.</td>
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<td>Cyber security vulnerability</td>
<td>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.</td>
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<td>Layered Optimization</td>
<td>Large-scale optimization problems are decomposed into multiple sub-problems at discrete layers of the electric system within a coordinated structure.</td>
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<td>Tier bypassing</td>
<td>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.</td>
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<td>Hidden coupling</td>
<td>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.</td>
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<tr>
<td>Latency cascading</td>
<td>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.</td>
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Takeaways

• Present DER coordination models exhibit considerable distribution operator bypassing, with the attendant issues of hidden coupling and cyber vulnerability.
  
  - Primarily due to use of Hybrid approaches

• Future models involve two schools of thought regarding coordination structure:
  
  - Centralized approach where the TSO performs all coordination, and
  - Layered approaches where a DSO has a significant role in coordination.

• Layered decomposition and the OCAM process can help organizations determine their most appropriate structure for T/D coordination.
Q&A
Questions States Can Ask

► What is the high-level structure of the existing or proposed coordination framework? (what is the industry structure?)

► What are the roles and responsibilities of each of the types of entities involved in T/D operational coordination? Do roles and responsibilities align with capabilities (can each entity carry out its roles?)

► What information is each type of entity expected to provide and receive?

► On what time scales are the entities expected to act to meet the overall cycle time target for clearing and dispatch? Does the industry structure create bottlenecks that lengthen cycle times (latency stacking)?
Resources for More Information

