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Grid Architecture and the Interactions of Power Systems, Markets, and Grid Control Systems

Jeffrey D. Taft, PhD
Chief Architect for Electric Grid Transformation

Pacific Northwest National Laboratory
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How Do We Understand Issues Like These?

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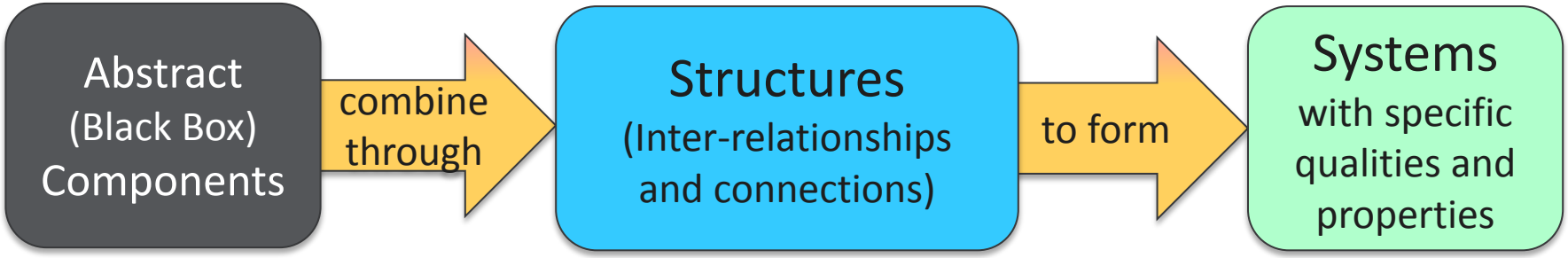
- What does the control structure for the whole grid look like? How does the grid behave as a *whole system*?
- What limits the ability of commercial buildings to supply energy or other services to electric grids?
- How do grid controls and wholesale markets interact?
- How does generation bifurcation impact regulation/oversight?
- How do DER's interact with ISO/RTO functions?
- How do agent-based autonomous distribution devices impact the Bulk Energy System?
- Are electric and gas networks converging or is generation just a downstream use of gas?
- Should distribution company roles and responsibilities be changed, and if so , how does this impact grid control, markets, and oversight?

System Architecture Definition/Purpose

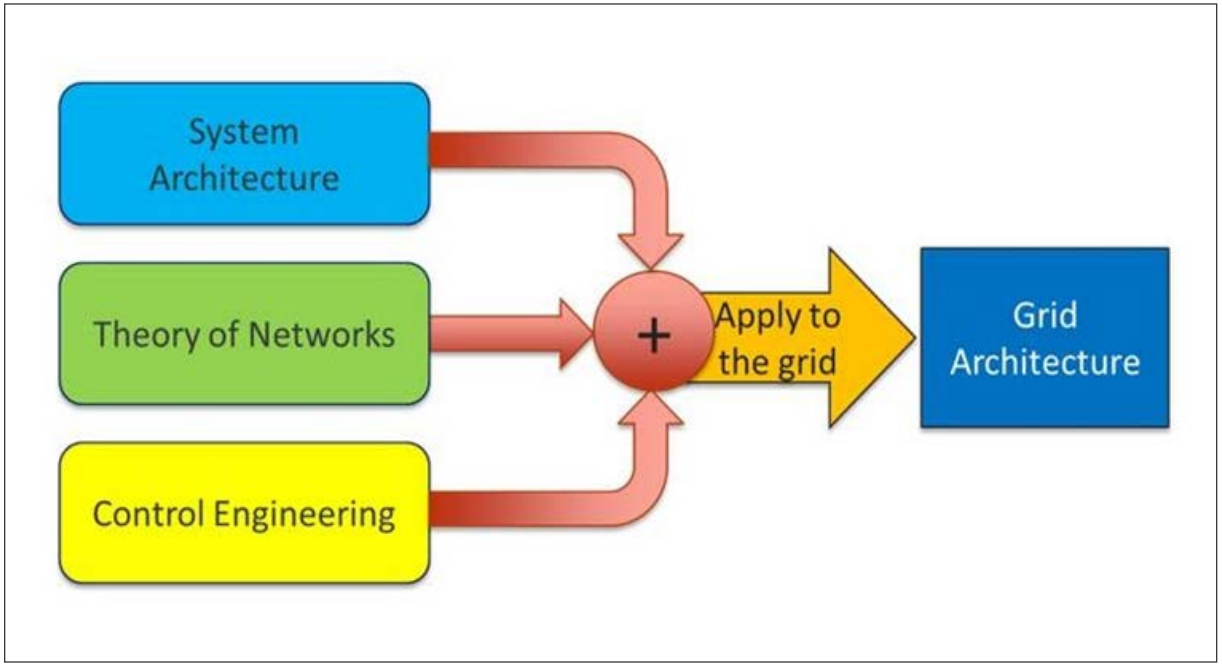
- A *system architecture* is a set of views of a (complex) system whose purpose is to help think about the overall shape of the system, its attributes, and how the parts interact.



The discipline arises from work at various organizations

What is Grid Architecture?

Grid Architecture is 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.

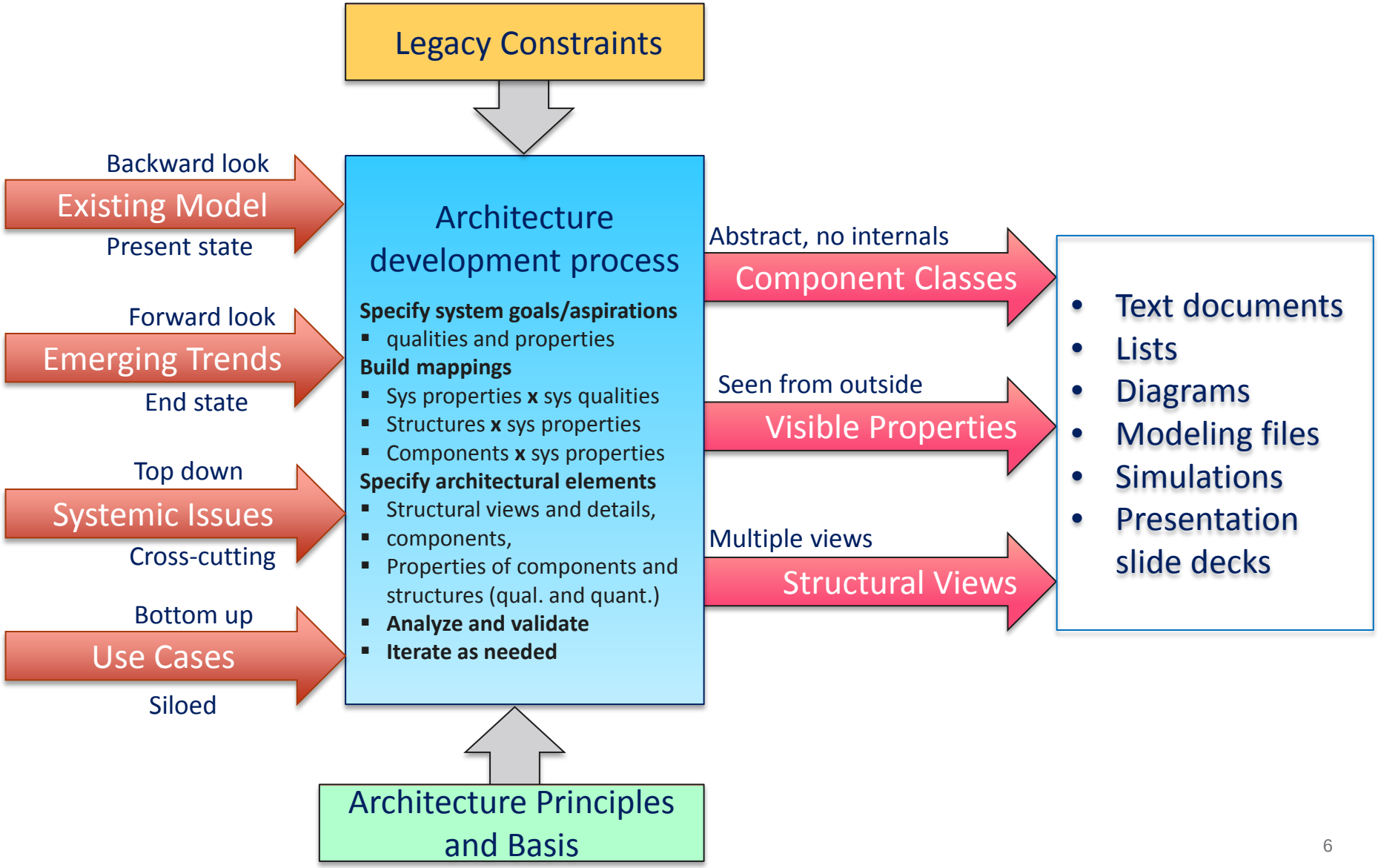


Some Uses of Grid Architecture

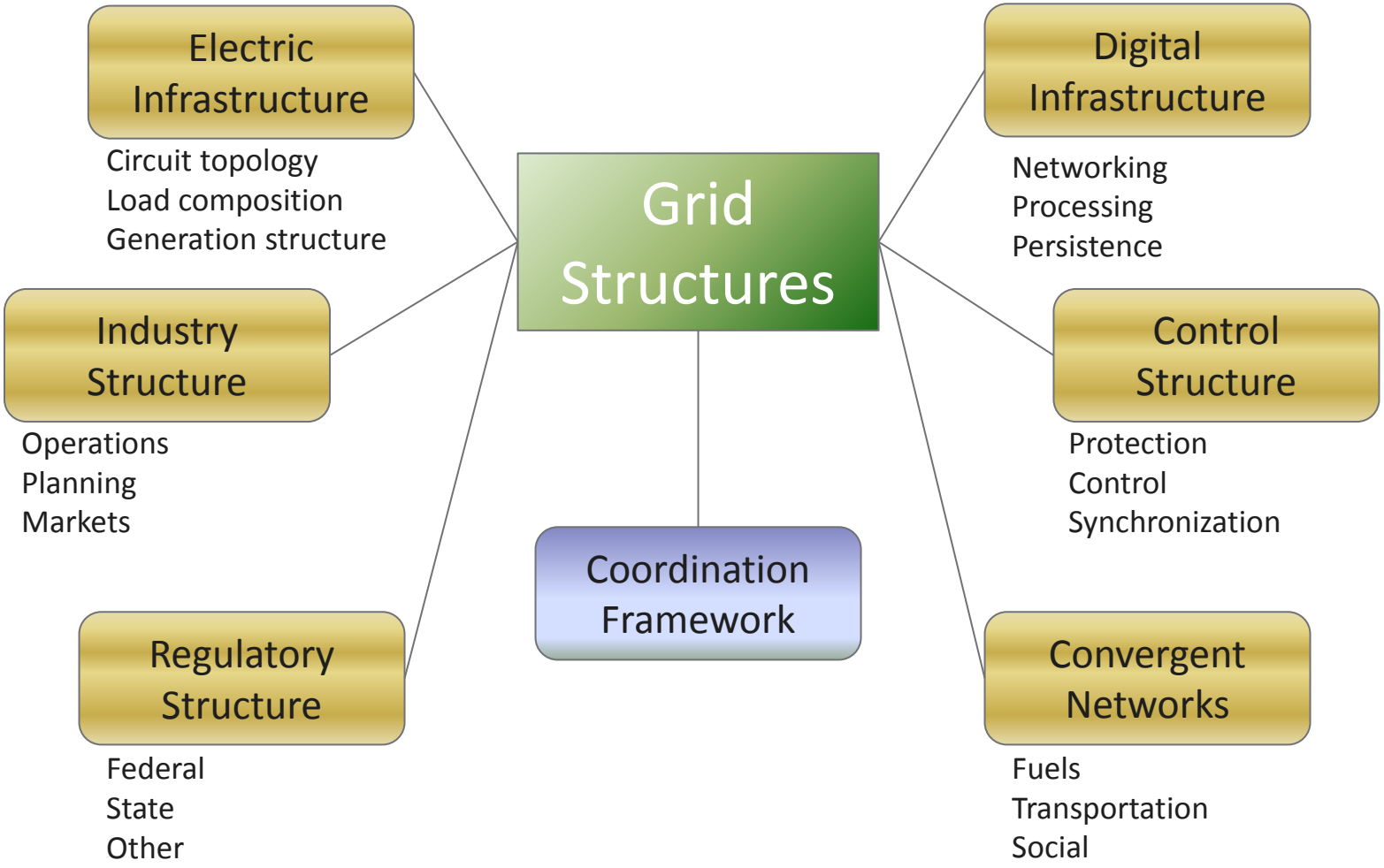
- Help manage complexity (and therefore risk)
- Assist communication among stakeholders
- Remove barriers and define essential limits
- Identify gaps in theory, technology, organization, regulation…
- Identify/define interfaces and platforms
- Enable prediction of system qualities

The architect is primarily a specialist in managing complexity.

What Goes Into A Grid Architecture?



Grid as a Complex Network of Structures



Grid Architecture Work with DOE

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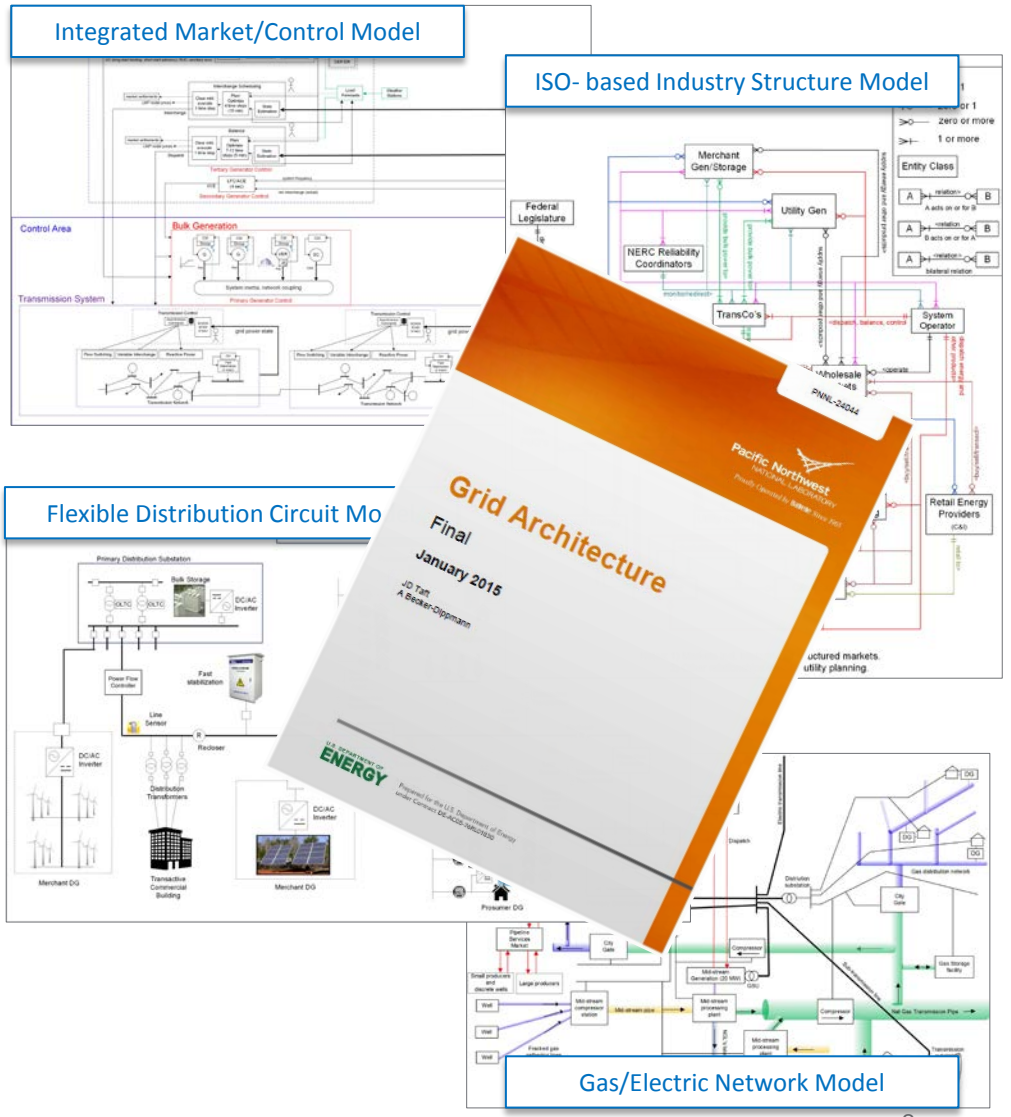
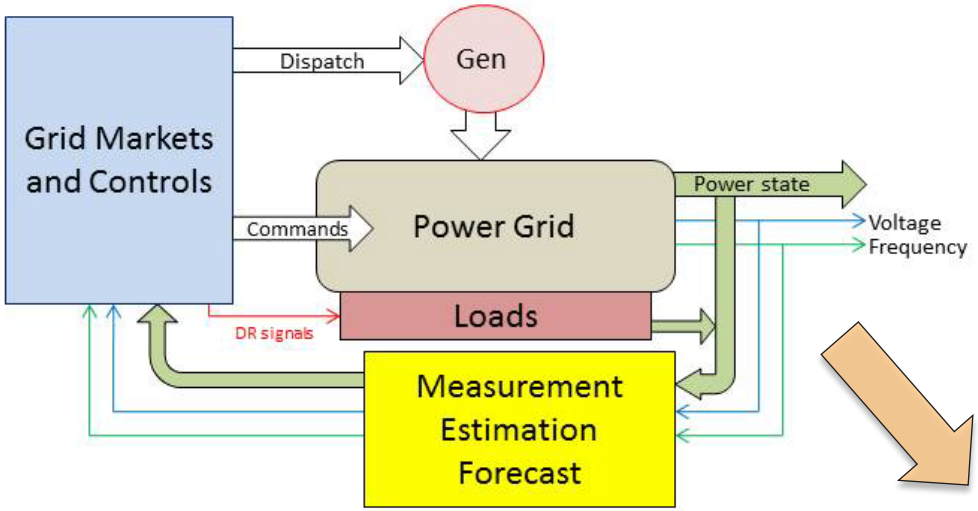
- Done as part of QER in 2014
  - Work focused on selected issues
  - 115 page main document plus support documents
  - 47 diagrams, 7 tables, 20 alternate architectures reviewed, 18 emerging trends and 39 systemic issues analyzed
  - Referenced and quoted in QER Report
- Work has started to go viral – being referenced in conferences and even has been used in an energy law class at GWU
- Presented to NY REV working group, resulting in engagement with NY REV on architecture
- Work continued under OE in 2015; will transition to GMLC in 2016



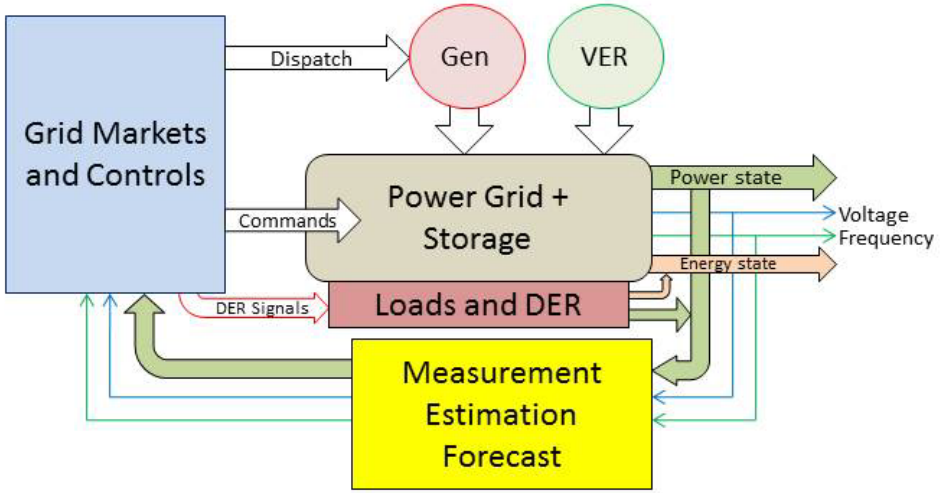
recent work related to DER

Evolution of Grid Control Due to DER



Old Model:
Power State Control with
Limits on Sys Frequency, Voltage

New Model:
Power State and Energy State Control with
Limits on Sys Frequency, Voltage



Emerging Industry Structure Change

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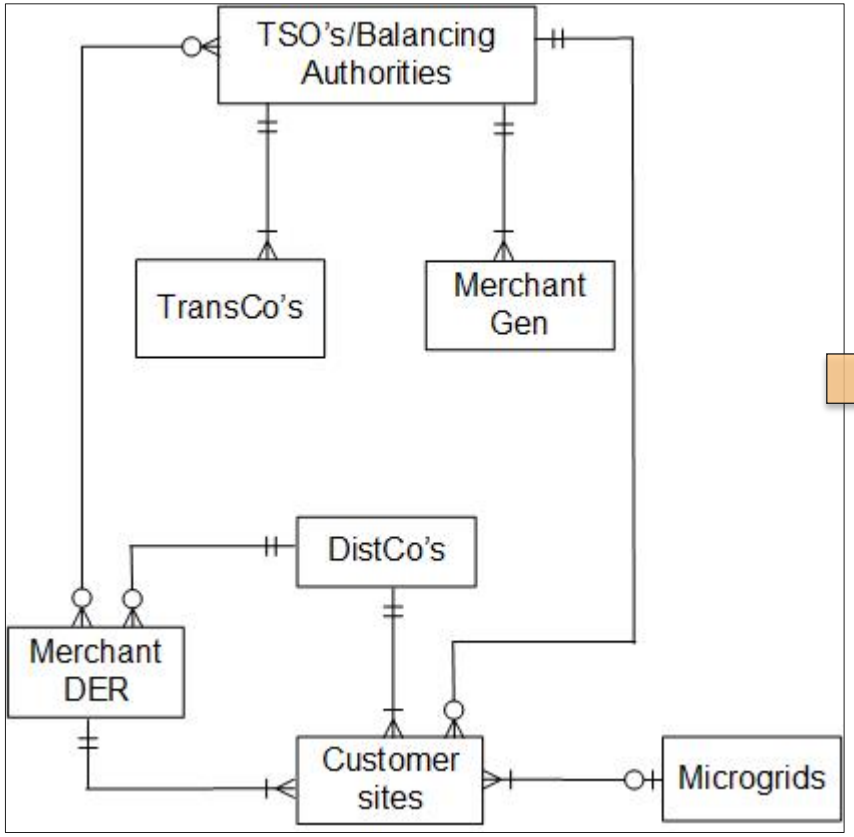
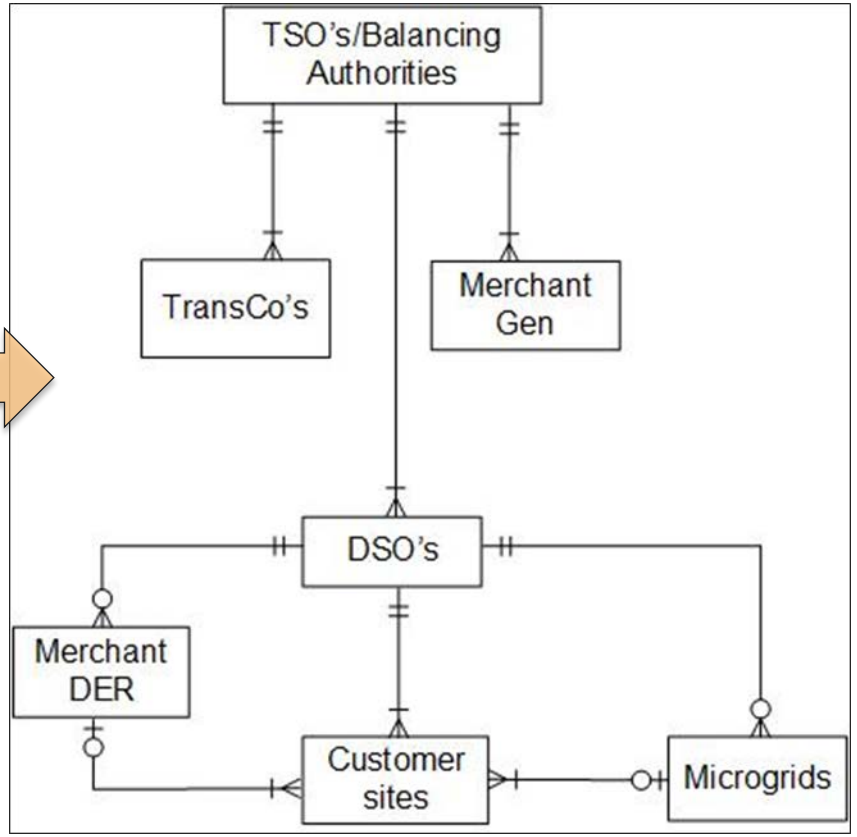
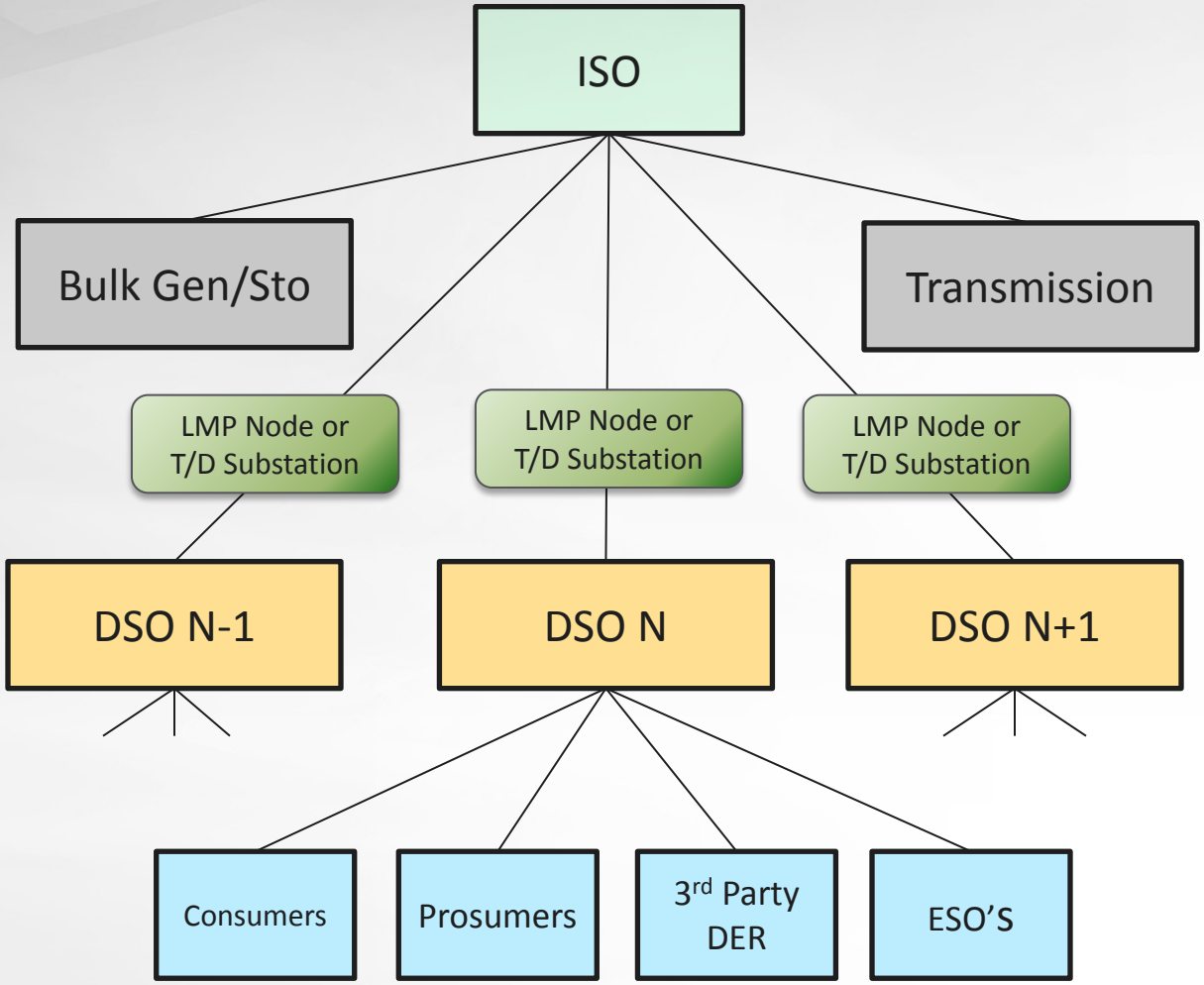
Traditional



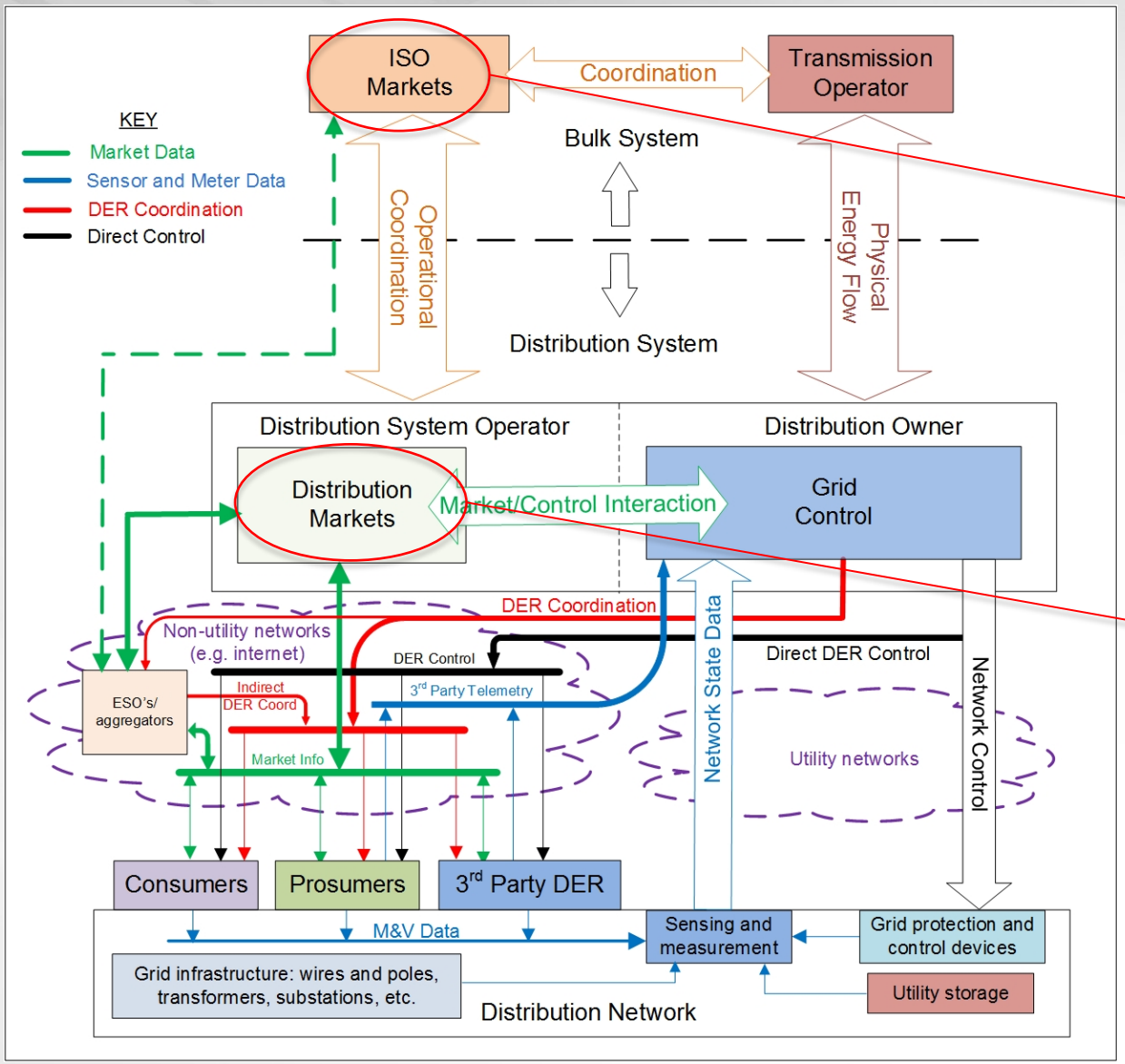
Emerging



Essential Structure for a DSO Model



Evolution of Two-Market Systems



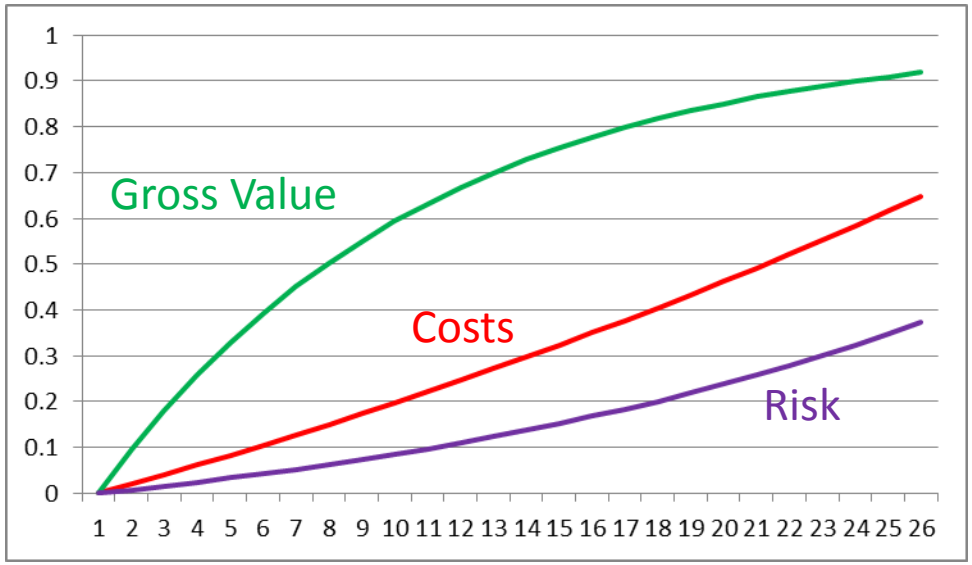
Existing Bulk Organized Markets

Emerging Distribution DER Markets

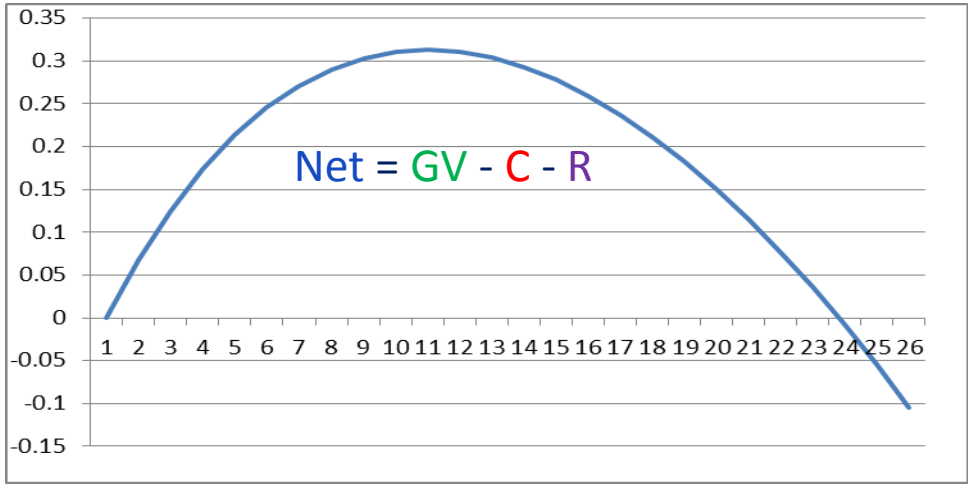
Effect of Granularity on Net DER Value*

- Bulk System
  - DER location is only weakly coupled to value as seen at the bulk system level
  - Granularity is barely visible
- Distribution System
  - All DER's have strong locational value components
  - Granularity can be completely visible if system is so designed

Distribution Component Curves vs. Granularity

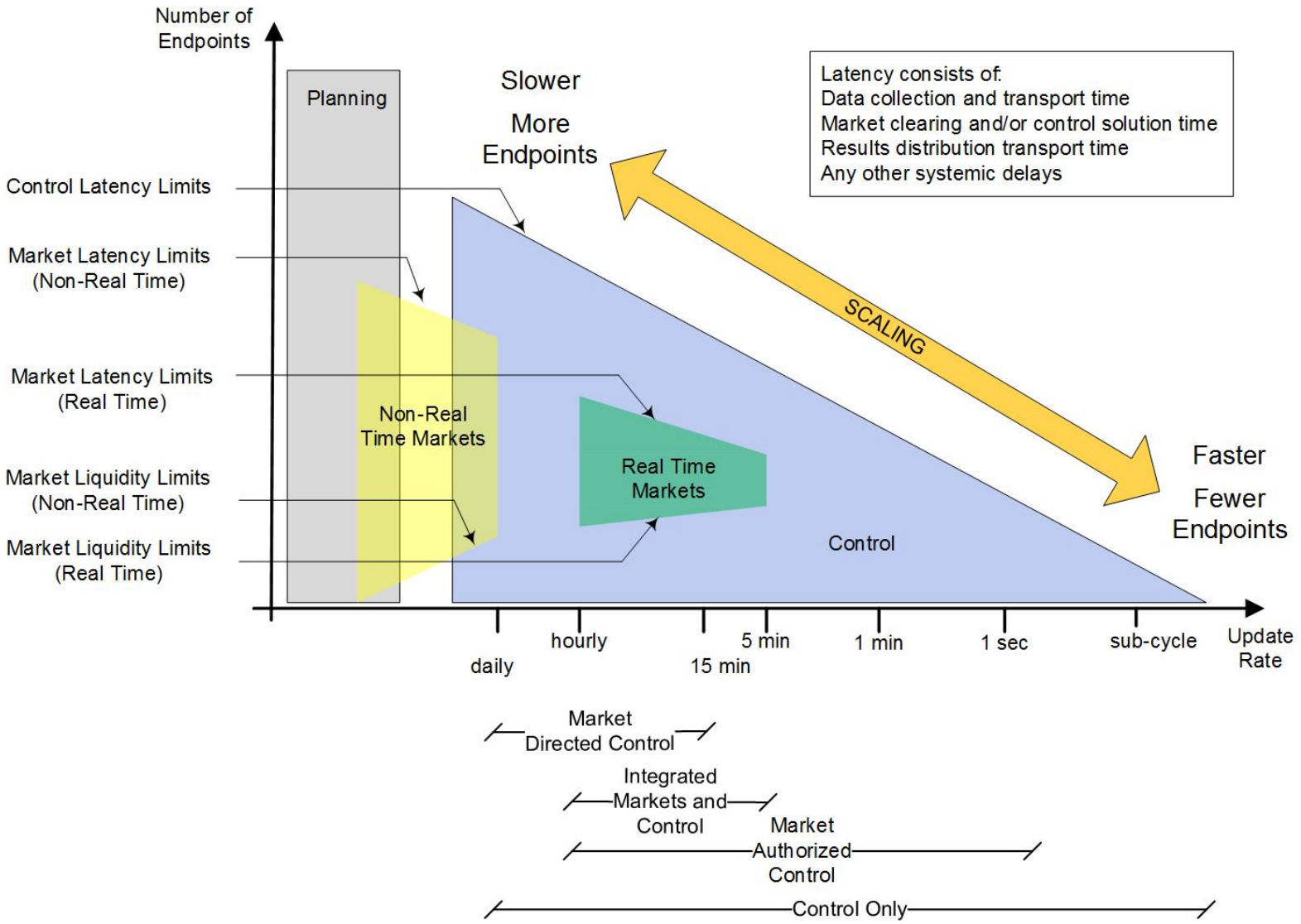


Net Distribution DER Value vs. Granularity



* Concept source: P De Martini, Resnick Sustainability Institute

Market and Control Interaction Regimes



Summary

- Grid architecture is a combination of system architecture, network theory, and control theory
- It provides a new way to think about electric grid complexity
- Architectural considerations related to DER involve multiple structures:
  - Industry
  - Control
  - Markets
  - Communications
- DER has implications for Bulk System and Distribution

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thank you

Jeffrey D. Taft, PhD
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jeffrey.taft@pnnl.gov