GRID ARCHITECTURE

Distribution System Evolution: Implications for Sensing and Measurement

EAC Panel Discussion

13 September 2017

Jeffrey D. Taft, PhD

Chief Architect for Electric Grid Transformation

Pacific Northwest National Laboratory

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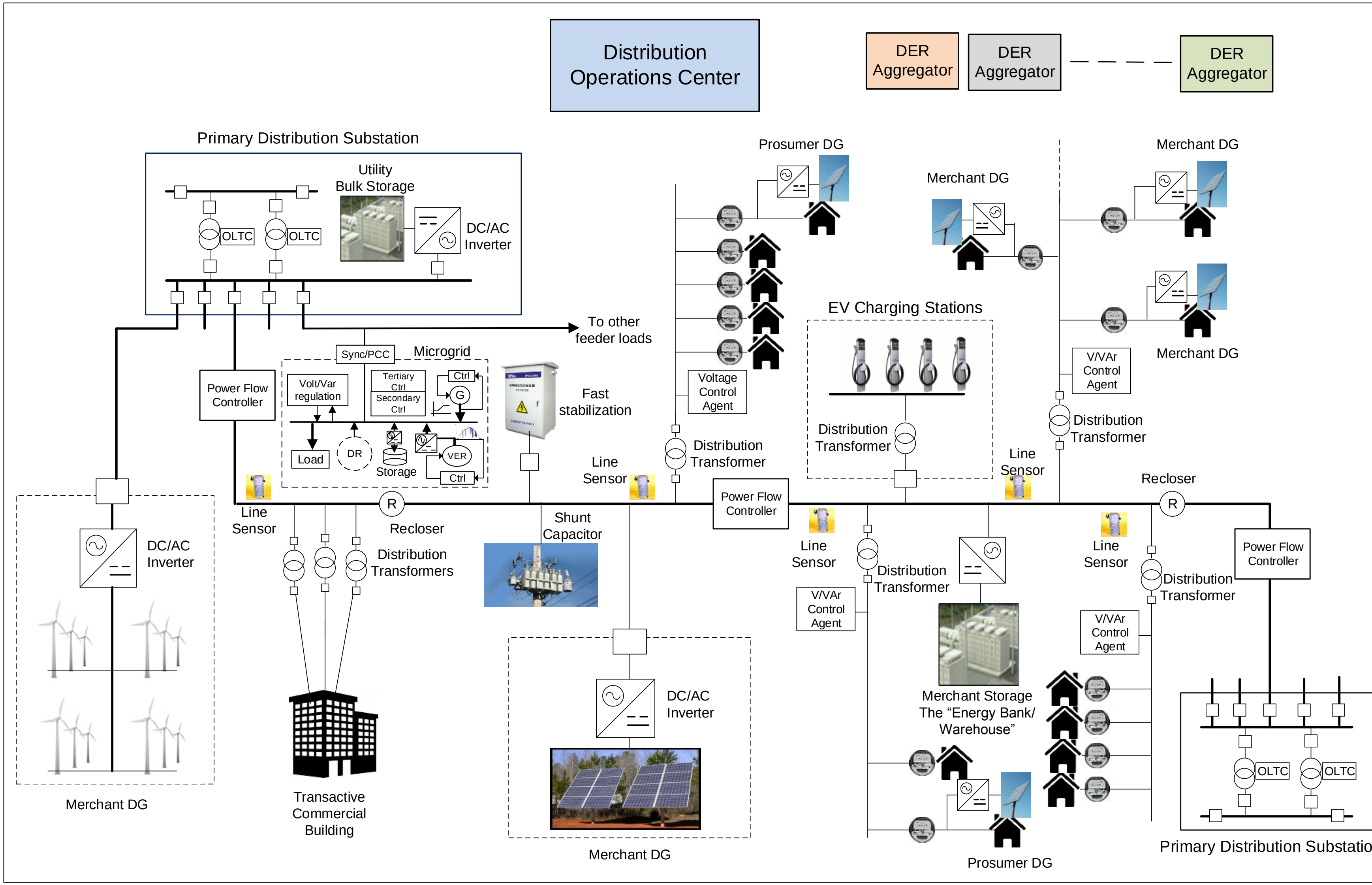
Pacific Northwest NATIONAL LABORATORY

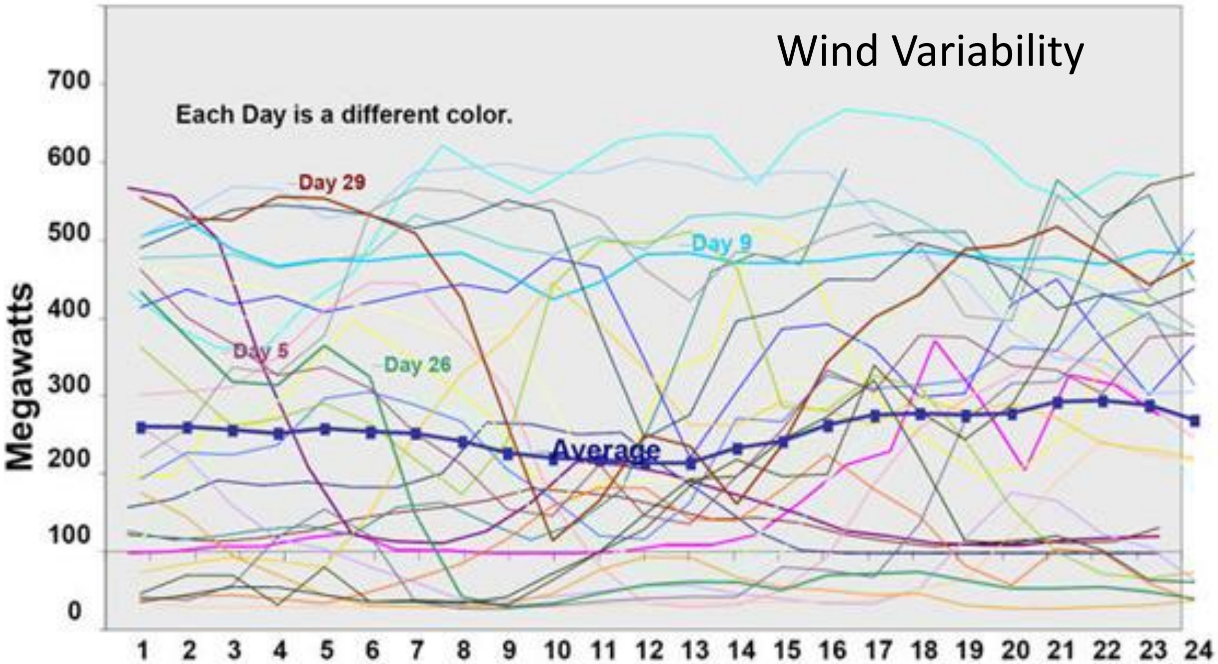
Topics

- Distribution Problem Domain Model
- Key Trends for Distribution evolution
- Present Status and Core Issues for Distribution Sensing
- Sensing and Measurement Implications for Grid Modernization

DER Problem Domain

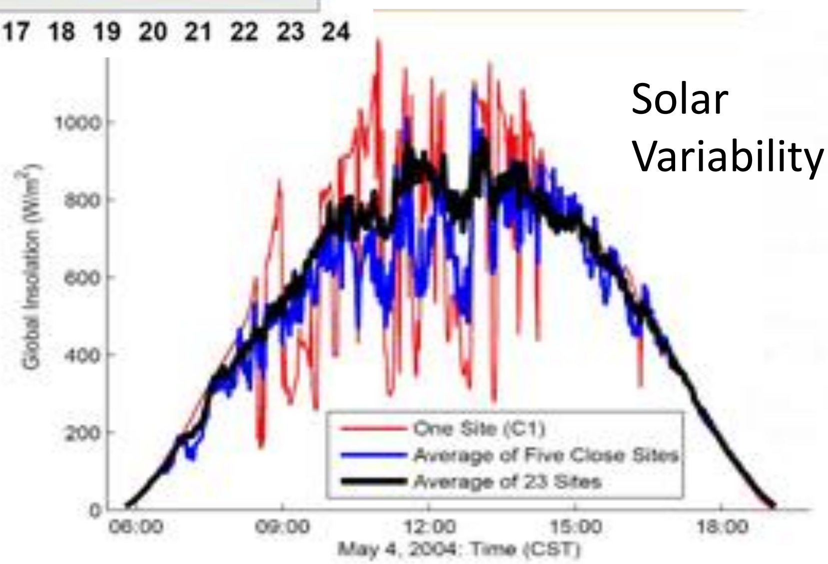


Trend: Renewables Integration Changes Grid Operations

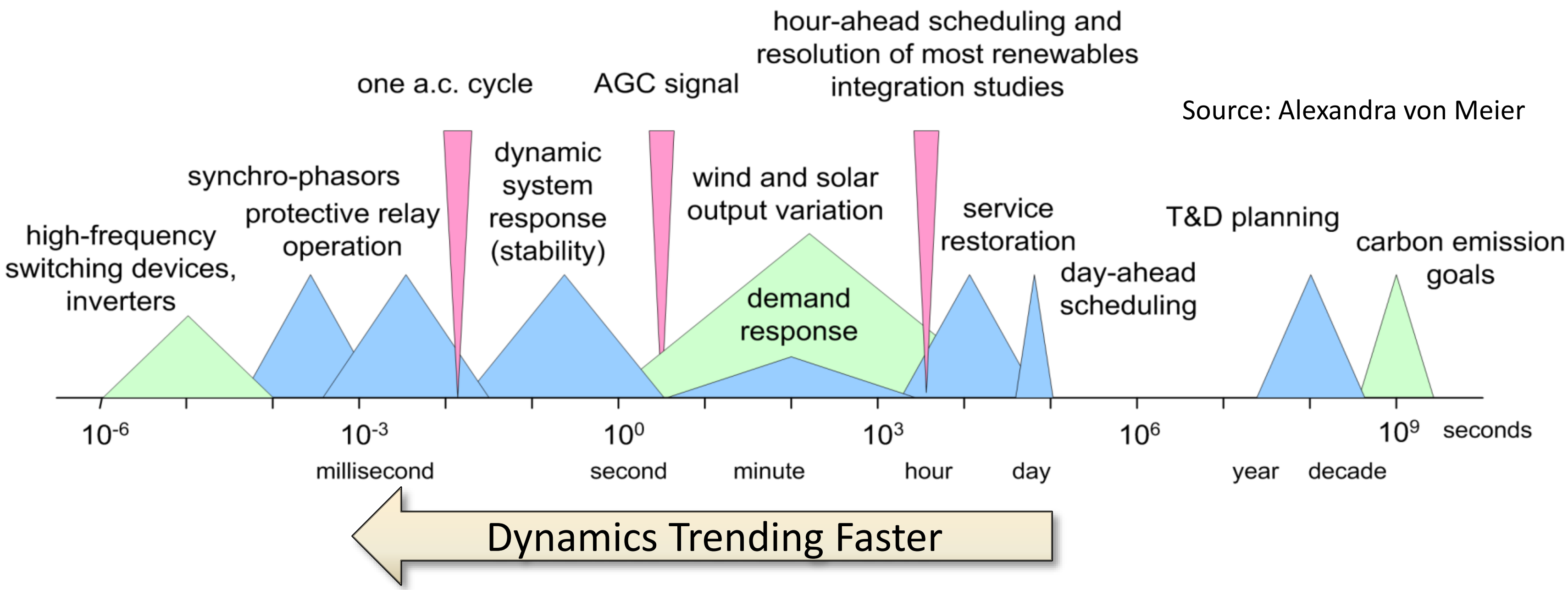


Introduces balancing and stability issues to the grid.

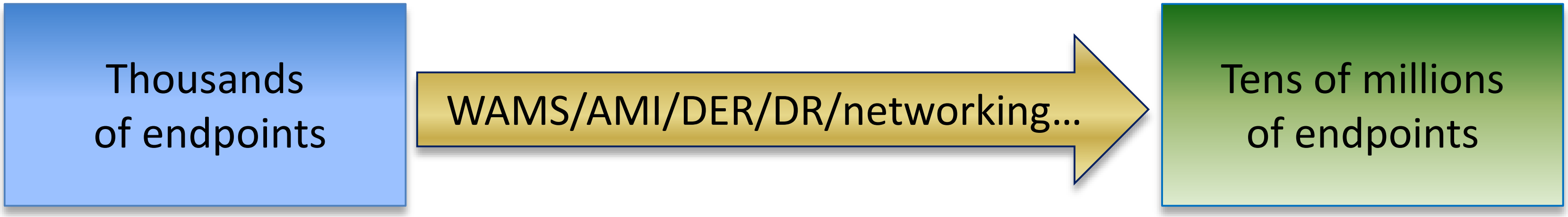
Introduces fast dynamics to the distribution system, affecting voltage regulation and system stability.



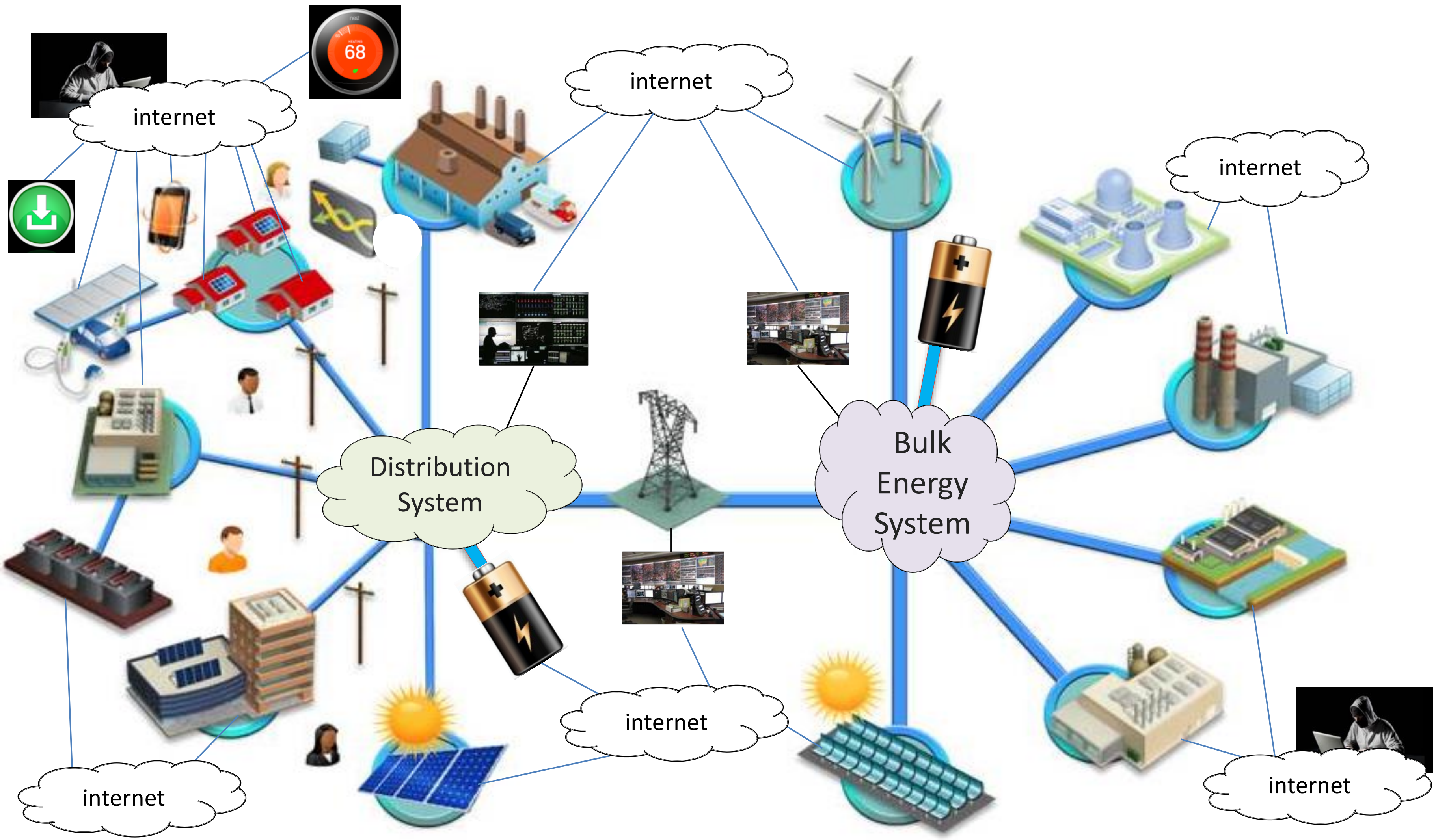
Trend: Less Time, More Data, More Endpoints



- Increasingly faster device/system dynamics
- Moving from slow data sampling to fast streaming data
- Massive numbers of sensing and control endpoints

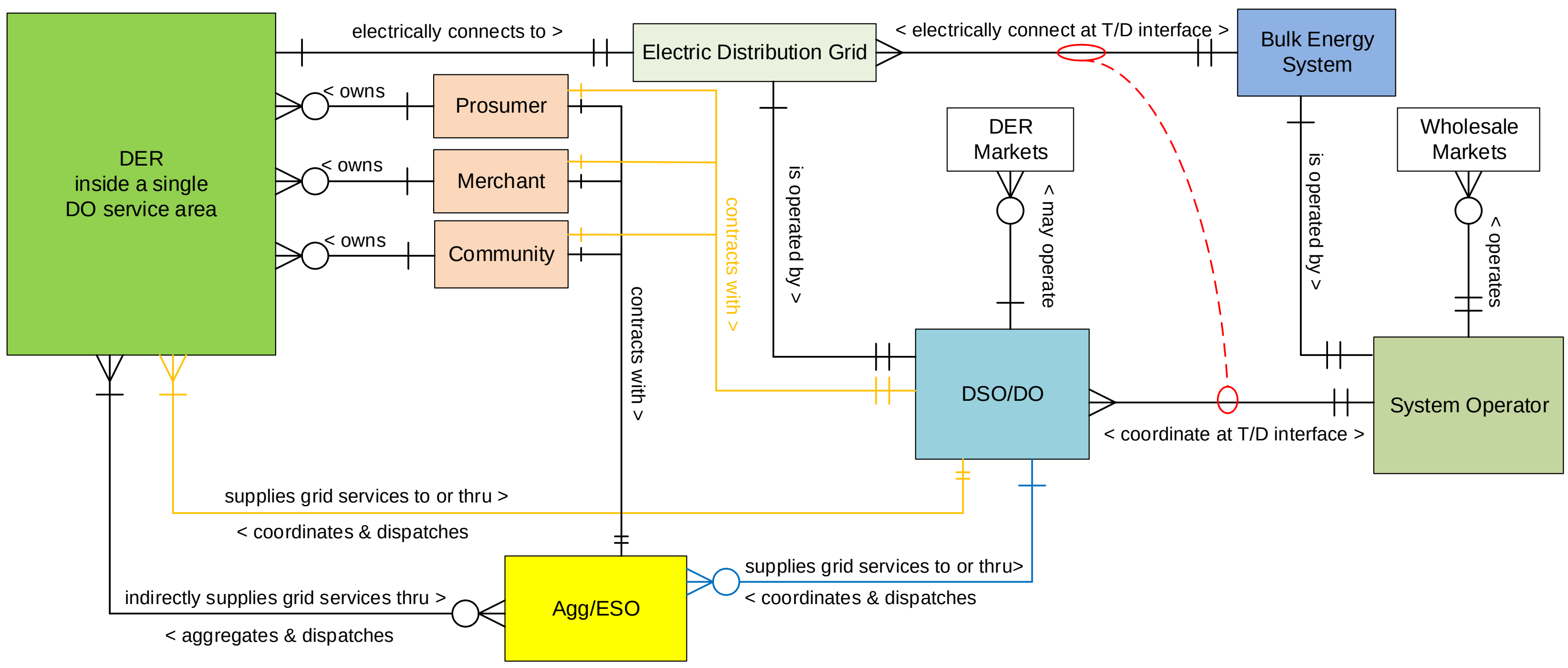


Future Distribution = Load + Gen Tie Point



Underlying diagram source: EPRI

Preferred DER Structure



Cardinality Symbol Key

- One; any particular
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DER Grid Services Entity-Relationship Diagram
Boxes represent entity classes
Lines represent relationships (read relationship text in direction of the arrow)

Note: all DER-based grid services are delivered to and through the electric distribution grids. The term “supplies” refers to the business arrangement.

Other Key Trends

Monolithic	Partitionable
Vertical siloes	Layers and platforms
Rigid/brittle	Cushioned/tensile
Weakly observable	Strongly observable
Coordination gaps	Pervasive coordination

DSOs will need superb distribution grid measurement capability to support demanding distribution grid operational capability.

Where Does Distribution System Sensing Stand Now?

- Many distribution systems have little or no distribution SCADA
- Many distribution substations have no SCADA
- Most existing distribution sensing is low speed and low capability
  - Mostly polled or exception reporting
  - Minimal sensing of grid variables
- Older AMI is not very useful for grid sensing; newer technology is improved but not widely deployed
- Communication networks for distribution are often weak, siloed, and non-converged
  - Poor performance (low bandwidth, lossy, insecure)
  - Not future-proofed
  - Cause high integration costs and complexity
- Poor grid topology model accuracy (needed for data context)
- Grid sensor installation is expensive

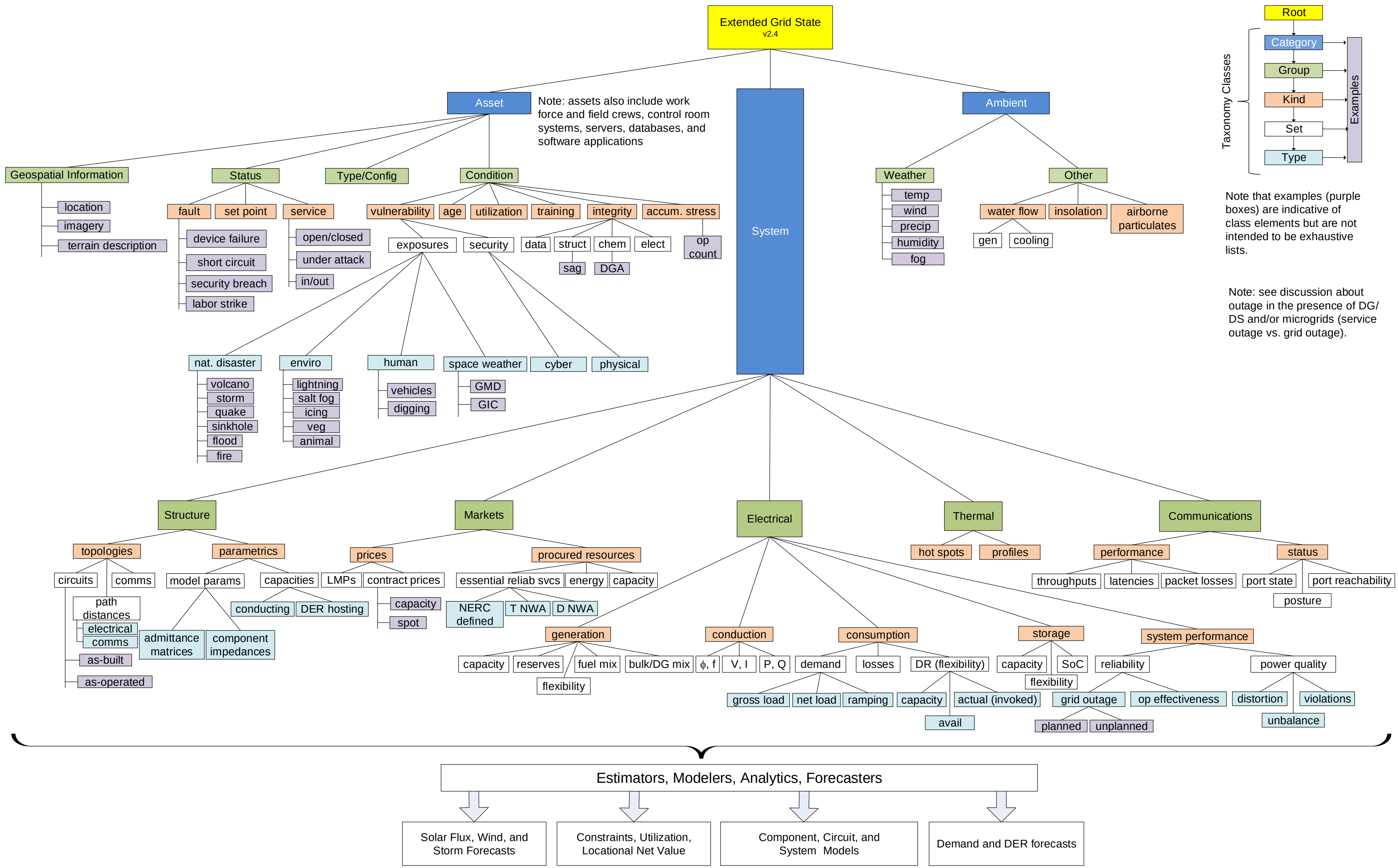
Common Distribution Grid Sensors

- Line sensors
  - Voltage, current, or both; compute real/reactive power, THD and harmonics
- Control device sensing
  - Voltage, current or both
- Faulted circuit indicators
- Premises meters – residential
- Premises meters – C&I
- Feeder meters
- Substation sensing
- Power quality monitors

Lindsey CVI Line Sensor

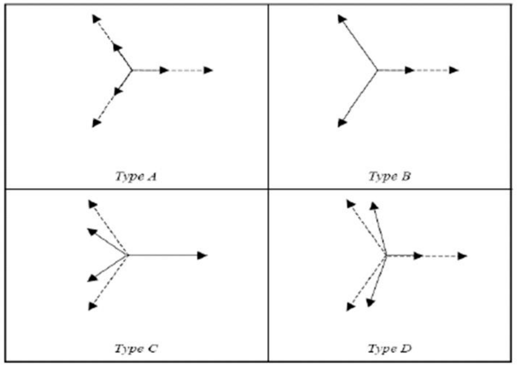
Fisher Pierce FCI

What Do We Need to Know for Distribution Grid Operations?

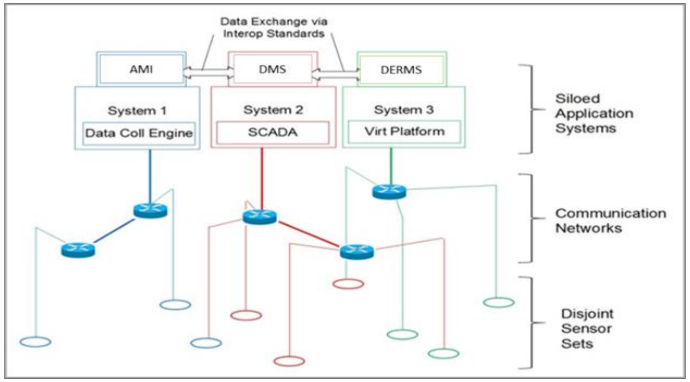


Distribution Grid Measurement Issues

- Control System PoV (grid state level)
  - Dynamic system snapshot
- Instrumentation PoV (AC waveform level)
  - Volt/VAr control; feeder phase unbalance
  - Real power flow (incl. direction)
  - Synchronization (DG, microgrids, power switching)
  - Fault detection, characterization & localization (3-phase AC methods) (e.g. methods of Bollen & Gu, Naidoo & Pillay, Krishnathovar & Ngu)
  - Asset utilization & asset condition
    - Many methods use complex impedance measurement

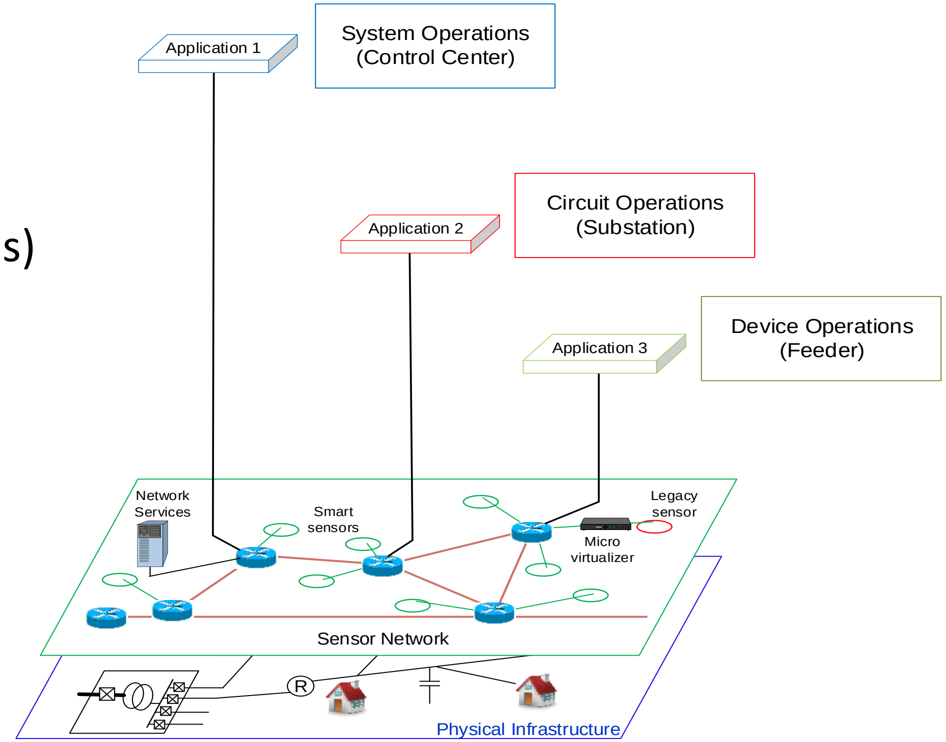


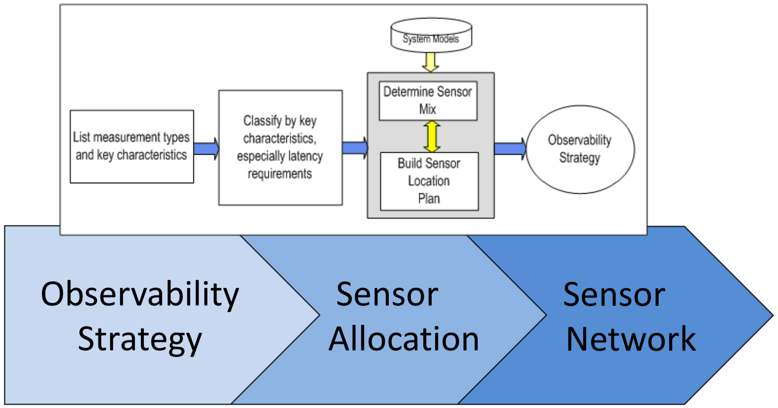
- Data Sharing PoV (application level)
  - Low latency multi-user access needed
  - High back end integration cost/complexity



Implications for Modernized Distribution Grid Sensing & Measurement

- Electrical Measurement
  - Fast waveform sampling
  - Magnitudes and phases (unbalanced)
  - High precision (small phase differences)
  - Timing/synchronization
- Architecture
  - Infrastructure layer
- Networking
  - Redundancy
  - Multicast streaming (SSM)
- Sensor technology
  - Grid topology sensing
  - Inexpensive installation
- Design
  - Observability methodology
  - Allocation tool





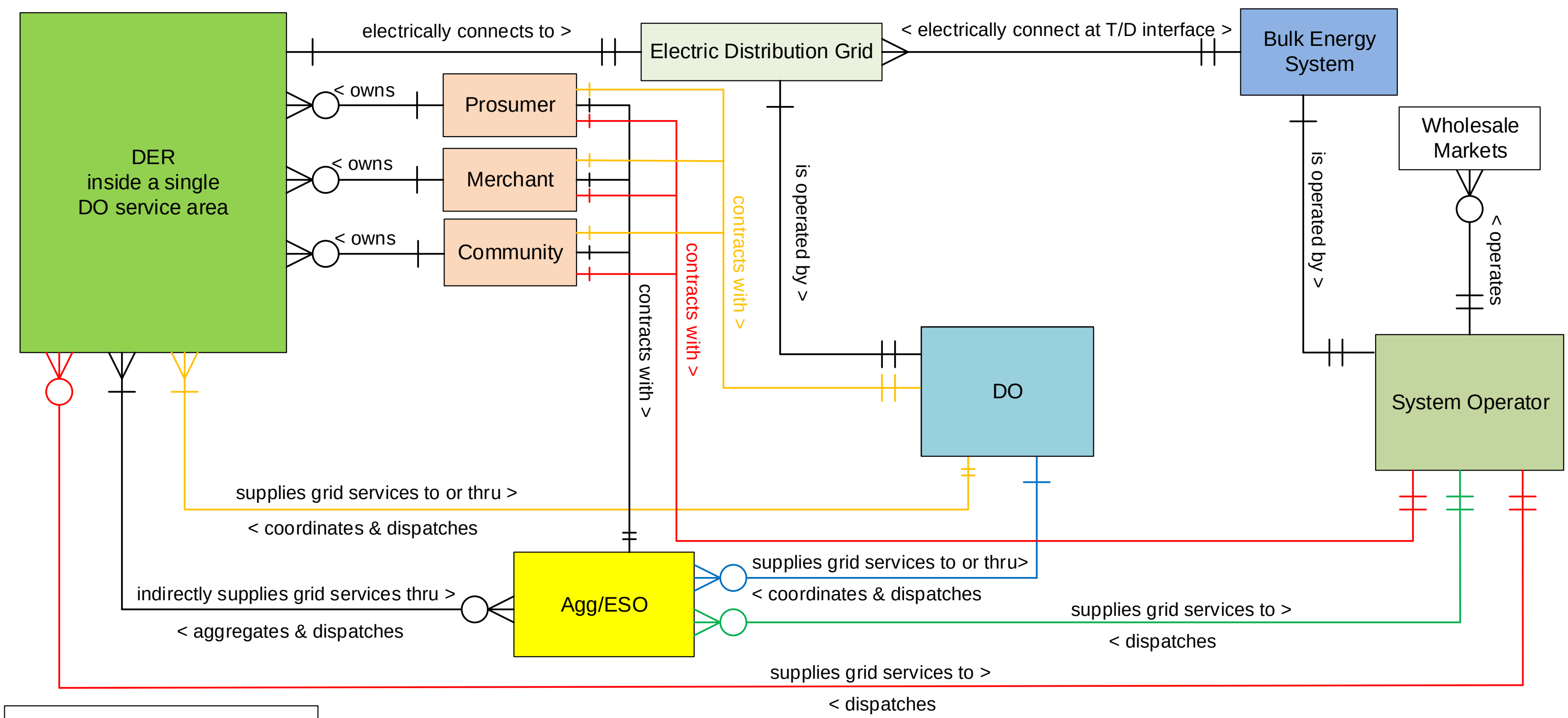
Final Comments

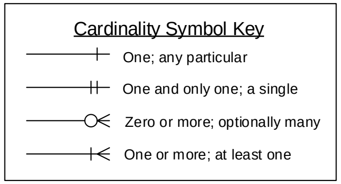
- 20th Century distribution grids did not need much observability
- Modernized grids with high DER penetration and advanced capabilities will need advanced sensing and measurement and data transport
  - Fast synchronized sensing & measurement
  - Adequate coverage (observability strategy-> sensor network design)
  - Inexpensive installation
  - Grid topology and system models
  - Volatility at the edge
- Sensing and networks as core infrastructure layer
  - Streaming sensor data
  - Timing distribution
  - Synchronized measurements
- Heavy lift for many distribution utilities to get to this level
  - Many advanced grid management schemes will have to wait until this level of upgrade happens

Thank You

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

Existing DER Structure





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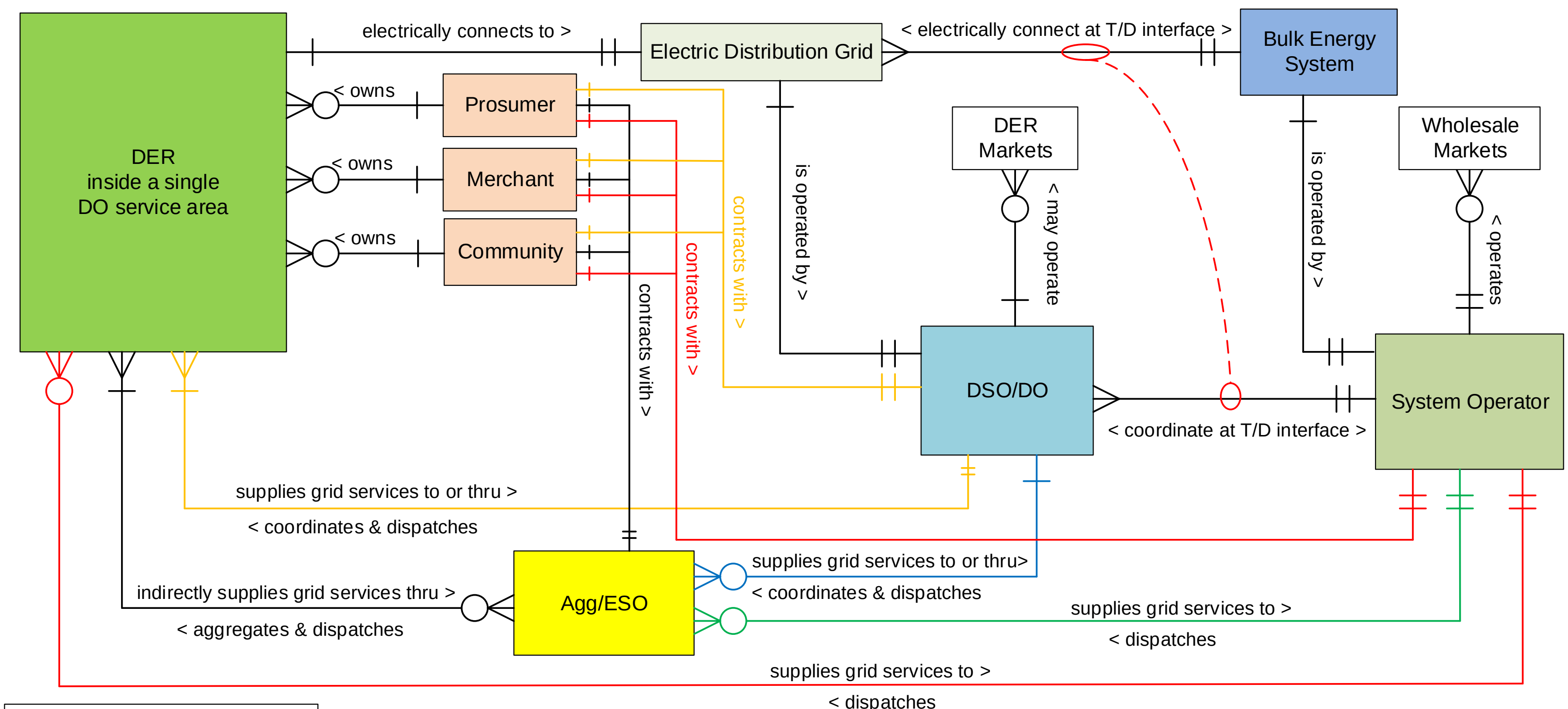
Likely Near Term DER Structure



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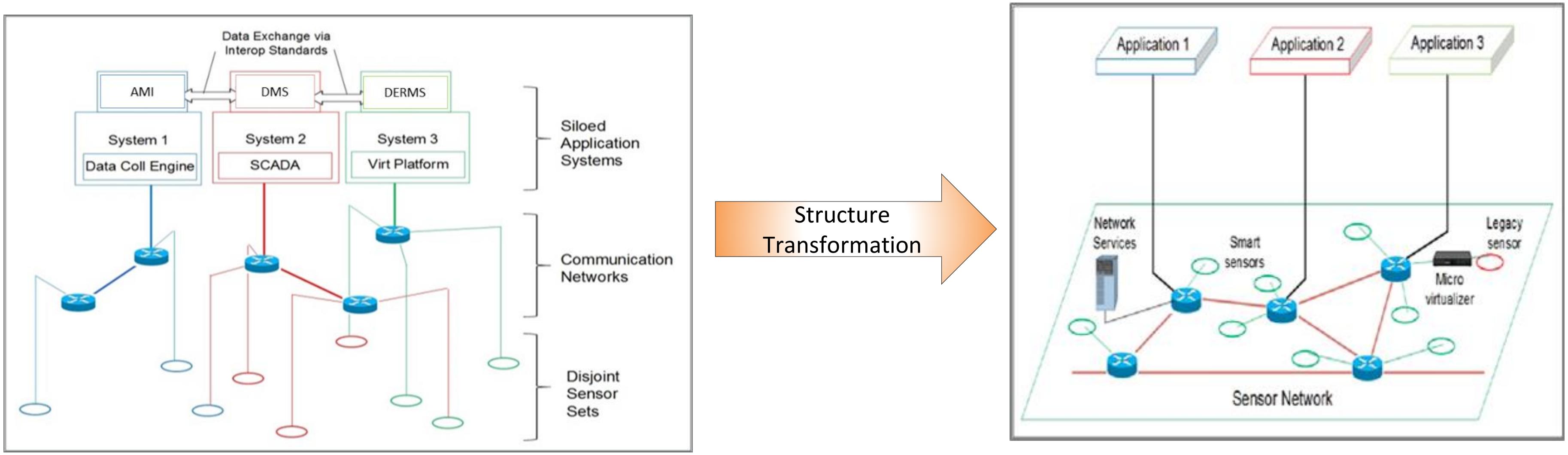
Separate Components from Infrastructure via Layering



- Siloed, coupled apps
- Long latency
- Poor flexibility
- Expensive integration

- Independent apps
- Low latency
- High functional flexibility
- Low cost integration
- Future-proofed investment

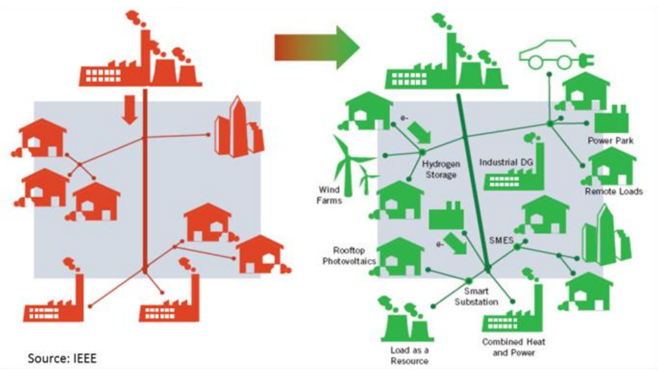
Hawaii PUC Docket No. 2016-0087, Order No. 34281, Dismissing Application Without Prejudice and Providing Guidance for Developing a Grid Modernization Strategy, Jan. 4, 2017 pp. 54-57

Electricity and Energy Systems are Changing Organically

- Business and operating models are being forced into change
- Grid economics is headed into new territory
- Consumer expectation and technology are bigger drivers than regulation or policy

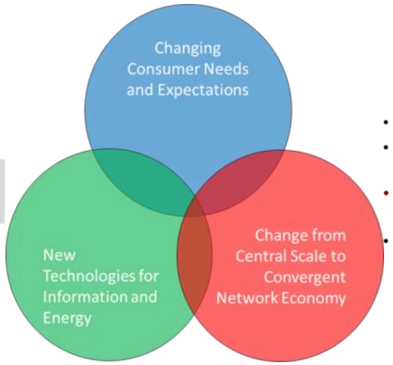
Grid Evolution: One-way Road to Grid of Things

Distribution grid becoming a multi-directional network integrating millions of intelligent devices, DER and back-up generation



Operating such a system requires greater situational visibility and collaboration with customers and their services providers

Source: P De Martini



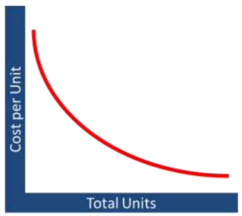
Grid as a Platform

- Grid as Back-up to customer self-sufficiency erodes grid value
- Business as usual enhances value through aging infrastructure replacement and operational efficiencies
- **Grid as Platform expands value through enabling DER integration at scale and utilization as a system and grid resource**
- Convergence model extends value through synergies between electric service and other essential networks such as water and transportation, often pursued in smart city initiatives

Source: P De Martini

Grid Economics Are Evolving

Economies of Scale



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Network Economics