An Architectural View of Emerging Changes to the Grid

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Transforming the US Electric System: Where State & Federal Initiatives Meet

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Seeing Grids Through the Lens of Architecture
US Utility Industry in Complex Transition

20th Century Electric Utility Mission:

- Keep the lights on
- Keep the lights on
- And, keep the lights on

21st Century Electric Utility Mission:

- Keep the lights on
- Be resilient
- Be clean and sustainable
- Be cyber-secure
- Be economical
- Be physically secure
- Be accessible
- Be flexible
20th Century Grid Design Principles

• Generation is central and dispatchable
• No significant energy storage in the grid
• Power must be kept in balance
• Generation follows load
• Distribution can be treated as a passive load depending from Transmission
• Real power flows in one direction only in distribution
• Voltage, reactive power, and system frequency are regulated
• Designed for reliability, not economy

We are in the process of violating most of these principles!
Emerging Structural Change

- Integration of renewable sources at T and D levels
- “Bifurcation” of generation structure
- DER penetration and local energy networks
The Ground is Shifting

• “Today’s value proposition for rooftop solar is pretty much avoid the grid financially but lean on it physically.”
  — Commissioner Champley (HI), April 2015

• “The combination of fast storage, advanced optimizing control, and power electronics can become a grid component that can enable the distribution grid to be a general platform for energy value stream innovation.”
  — Grid Architecture Report for EPSA/DOE, January 2015

• “…handling scaling issues that will arise as hundreds of millions of endpoints become active participants in the power delivery process.”
  — CEC blog, August 2014

• “Under the customer-oriented regulatory reform envisioned here, a wide range of distributed energy resources will be coordinated to manage load, optimize system operations, and enable clean distributed power generation.”
  — NY DPS Staff Straw Proposal on Track One Issues, August 2014
Responses

• All three CA IOU’s now say their distribution grids will be open access networks
• TSOs may become energy cloud service providers to the DOs
• Structural changes
  – DER/microgrids/LENs
  – DSO models
• Enlarging Scope:
  – Integrated Networks
Many Potential Co-Existing Futures

Modernization

Localization

Business as Usual

High end automation, high DER penetration, etc.

Increasing local energy determinism: DG, multi-user microgrids, CCA, etc.

Less automation, some DER penetration

Large IOUs, some PPAs and verticals

Smart Cities

Coops, rural utilities

Some PPAs and verticals

Technological Complexity
Any Grid Change Has A Context

Any change exists in the context of the Network of Structures:

- Electric
- Industry
- Regulatory
- ICT
- Control
- Coordination
- Other convergent networks

Architecture principle: We must be cognizant of the whole system when optimizing subsystems.
Grid Complexity

- Decentralized data, development, and control
- Inherently conflicting diverse requirements
- Continuous (or at least long time scale) evolution and deployment

- Heterogeneous, inconsistent, and changing elements
- Geographic distribution
- Wide time scales
- “Normal” failures
Changing Grid Management Problem

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

New Model:
Power State and Energy State Control
with
Constraints on Sys Frequency, Voltage
Storage: A System View

Storage may become a key multi-use grid technology:

- Stochastic generation smoothing
- Net load shaping
- Building energy management
- Outage mitigation/reliability
- Virtual inertia grid stabilization
- Damping/grid stabilization
- Electric transportation
- Demand ramp management

“Bilaterally fast storage” – DOE QER Report 2015
Mixed DER Environment

DO Operations Center

Primary Distribution Substation

Utility Bulk Storage

DC/AC Inverter

OLTC

DC/AC Inverter

Fast stabilization

Voltage Control Agent

Distribution Transformer

Line Sensor

Recloser

Power Flow Controller

Load (DSM) Storage

Microgrid

V/Var regulation

Power Flow Controller

DC/AC Inverter

Merchant DG

Transactive Commercial Building

Merchant DG

Prosumer DG

Merchant DG

EV Charging Stations

ISO/RTO/BA

DER Aggregator

Remote Building Energy Manager

Merchant Storage Operator

Merchant Storage

The "Energy Bank/Warehouse"

V/Var Control Agent

Secondary Ctrl

Line Sensor

Distribution Transformer

DC/AC Inverter

ISO/RTO/BA

Der Aggregator

Remote Building Energy Manager

Merchant Storage Operator

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DC/AC Inverter
The Mixed DER Coordination Problem

- Functional capabilities overlap for some DER
- Not all DER perform the same way
- How should mixed DER be allocated/dispatched?

![Diagram showing various DER components and their interactions with the distribution grid and operator grid controls.](image-url)
**DER Locational Value**

- DER value accrues differently at different levels of the grid

**Implications:**
- Need for coordination at T and D levels in use of DER (markets & control)
- Need for integrated resource planning
- May imply need for regional planning coordination

Source: P De Martini
Distribution Structure Change

Traditional

Emerging
Peer-like Relationship of DSO and ISO

Consumers
Prosumers
Communities
Services ecosystems

New Interfaces

Bulk Energy as a Service
Gen/Storage in the “eCloud”

Underlying diagram source: EPRI
Evolution of Two-Market Systems

Existing Organized Wholesale Markets

Emerging Distribution DER Markets
Distribution Grid Value Paths

- Modernization
  - High end automation, high DER penetration, etc.
- Localization
  - Increasing local energy determinism: DG, multi-user microgrids, CCA, etc.
- Business as Usual
  - Less automation, some DER penetration

Grid as Backup  Current Path  Grid as Network  Convergence

Value of the Grid

Source: P De Martini, More Than Smart, A Framework to Make the Distribution Grid More Open, Efficient, and Resilient
Network Convergence

• System integration is the connection of various components and subsystems so that the resulting overall system can deliver some specified set of capabilities

• Convergence is the transformation of two or more networks or systems to share resources and interact synergistically via a common and seamless architecture to enable creation of new value streams

• Convergence often results in new platforms that enable the new value streams
Network Convergence/Platform Formation

• Dependency
• Integration
• Convergence
Where Does Convergence Occur?

Power Grids

Information and Communication Networks

Financial Networks (Markets)

Social Networks

Convergence occurs at the grid market/control systems

Flexibility here makes or breaks new business models
IoT: Tool or Vulnerability?

- Internet of Things: devices with data processing and communications capabilities
- Mostly use internet for communication
- Defined as machine-to-machine communication/interaction
- Case 1: IoT devices are electrically connected to the grid and internet
- Case 2: a crucial grid asset is subjected to massive IoT bot attack
Final Comments

• DER penetration is changing the structure of the grid
• Technology advances can help and also create new vulnerabilities
• Public policy and consumer expectations are changing utility business and technical models
• The nature of the T/D interface is changing
• Implications for:
  – Federal and state regulation and policy
  – Planning processes, controls, and market designs
• Grid modernization requires that these complex issues be considered in the whole grid context
Thank You

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