Microgrids: the Essential Architecture for Smart Energy

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We want rapid innovation and distributed energy

• Central control requires simplification and homogeneity
• Volatility of Supply
• Rapid change of Technology
• Unable to determine changing best application of changing supply to changing demand.
First NIST/Department of Energy Smart Grid Workshop, April 2009

William Cox Keynote *Achieving the Smart Grid Vision*

BACK TO THE FUTURE...
Vision—Collaborative Energy

• Providers and consumers of energy
• …Cooperating and working together
• …With control mediated by markets
• …And leveraging existing work

Don’t reinvent.
Build on the present.
Consider the past.

SOURCE: William Cox Keynote, First NIST/DOE Smart Energy Workshop 2009. See also “Smart Loads and Smart Grids”—both on Cox Software Architects web site
AND BACK TO OUR TALK IN PROGRESS...
Break up the span of control, isolate diversity, empower consumers:

**Microgrids**
WHAT ARE THE CHARACTERISTICS OF MICROGRIDS
What Are Microgrids?

- Each microgrid may always or sometimes be disconnected from other grids.
- Microgrids are self-managing
- Different microgrids have different purposes
- A microgrid MAY be a component in a larger microgrid
- A microgrid may be composed of smaller microgrids
Microgrids are already all around.

- Industrial Microgrids
  - Includes District Energy
- Isolated Microgrids
- Development Microgrids
- Military Microgrids
- Motivational Microgrids
- Hidden Microgrids
  - Post-Sandy Experience
The central issue for each microgrid is optimum allocation of energy

- Distributed Energy is local energy
- Priorities and purposes for each source and use of energy are ever changing
- Each microgrid presents a classic knowledge problem
- Markets are tested means to operate control systems
- OASIS Energy Operation defines market interface for any agent or system.
OASIS Energy Interoperation provides semantics and interaction patterns for energy market interactions

USE TRANSACTIVE MARKETS TO SOLVE KNOWLEDGE PROBLEM
Energy Systems interact with Micromarkets

Cloud-based Micromarket

Agent Interface

Energy System

[Diagram showing energy systems interacting with cloud-based micromarkets through an agent interface]
Each Agent competes in market to optimize its own system performance.
Agent functionality can be re-located to support legacy or low-capability systems.
Market interactions do not change if some systems are not agent-capable.
Many grids means diversity of purpose as well as of technology

THE ARCHITECTURE OF MICROGRIDS
At the edge, Micromarkets of low-capability systems can resemble legacy integration.
Vehicles may require some additional services, but do not challenge the model.
Microgrids are themselves energy systems that can interact in larger microgrids (Recursion)
The type of system represented by the agent does not change the market interaction.
APPLYING MICROGRIDS—STRUCTURED ENERGY & FAULT RESILIENCE
Structured Energy: Relationships

• Microgrid relationships: recursive definition

• A microgrid is an aggregation of one or more microgrids which provides energy switching, transportation, and management across its constituent microgrids

• This creates a hierarchical structure where the edges are from a microgrid to its constituent microgrids
Structured Energy Conclusions

• Microgrids form a topology over components

• A model and tools for
  • Assembling microgrids
  • Disassembling microgrids
  • This paper—grid resilience using these techniques

• Structured Energy takes advantage of smoother and better managed loads
  – Reduction in complexity
  – Simplified collaboration and management
• Assume single fault at $M$
• Affected microgrids in $G$ are
  – $L$, the Parent of $M$
  – $M$’s siblings
  – $M$’s children
An Illustration
An Illustration (2)
Architecting for Fault Resilience

• Distributed resources must be distributed and diverse, both geographically and in control/management
  • E.g. Storm Sandy issues with PV that couldn’t be used because of failures remote from the DER

• Multiple connections for both communication and energy flows increases the resilience by increasing feasible aggregations

• Structured fault containment reduces risk of new technology and interactions
Fault Resilience Summary

• Applies techniques used in network fault detection, communication path management

• Independent of the underlying technologies—uses interconnection and service capabilities
  – Fault drives containment and reintegration
  – Allows independent evolution and reinvention (SOA)

• Simple algorithms—no variation based on component implementation
  – Easier automated implementations
Questions
Markets for Control


Energy-Related OASIS Specifications

• OASIS Energy Interoperation
  – Designed to work to, from, inside, and outside microgrids
  – Committee Specification ballot in process
  – http://www.oasis-open.org/committees/energyinterop

• OASIS Energy Market Information Exchange
  – Price and product definition/description
  – Transactional EMIX Notes
  – Committee Specification pending publication
  – http://www.oasis-open.org/committees/emix
Knowledge Problems and Spontaneous Order
