Structured Energy: A Topology of Microgrids

William Cox, PhD
Cox Software Architects LLC
Toby Considine
TC9, Inc
William Cox and Toby Considine

• Participants in developing NIST Smart Grid Framework and Roadmap
• Leaders in collaborative energy
• Cox
  – Consulting Software Architect
  – Definition and structure for interoperation
  – Venture and startup guidance and technologies
• Considine
  – Informational standards for building design, operation, energy use
  – Strategic Technology Consulting in emerging markets and Venture Formation
Introduction

• How do we assemble larger microgrids from smaller?
• What is well-behaved microgrid for energy?
• How do we collaborate across microgrids?
• Why would we assemble microgrids from devices and microgrids?
• We describe formal terminology for union and intersection and how to expand or narrow collaboration accordingly
Managed and Collaborative Energy

- **Managed Energy**
  - Managed to different goals
  - Scale and control are issues

- **Collaborative Energy**
  - Choices consistent with business goals
  - Consider markets and requirements
  - Ask versus *tell*

- **Balancing Energy Supply & Demand**

- **See Cox and Considine, “Smart Loads and Smart Grids—Creating the Smart Grid Business Case,”** Grid-Interop 2009
An Illustration
• Microgrids [Galvin]
  – “[Microgrids] achieve specific local goals, such as reliability, carbon emission reduction, diversification of energy sources, and cost reduction, established by the community being served.”
  – “[S]mart microgrids generate, distribute, and regulate the flow of electricity to consumers, but do so locally.”
• Microgrids can be considered to be **self-managed**
Structured Energy: Relationships

- A **microgrid** is a group of devices with self-management, and optionally
  - Storage,
  - Generation, and
  - Consumption of energy

- 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**
Self-management Is Key

• Consider a Microgrid as an abstract object with information and operations, some private
  – Provide an interface to the outside
  – Private operations to the inside
• Struggle over knowledge and control
Information within a Microgrid

• Information within a microgrid comes from
  – Other components
  – Aggregated or summarized by contained microgrid management systems (MGMS)
  – Markets (specific to the microgrid or external) for information sharing and coordination
  – In Structured Energy microgrids are the fundamental building block
• Clarify the definition of a microgrid:
  • Inside-the-node generation, storage, and consumption are each optional (but must have one)

• “Local” is a flexible term
  – The critical question is “is the node self-managed”

• “Micro” is a flexible term
  – Some use the term “nanogrids” for small microgrids [in this conference]
  – Commonality of interest and location is more important than mere size
  – How big is no longer “micro”?
    • These definitions work for “the big grid” as well
Why an Algebra?

• An algebra is a structure
• Take $\mathcal{M}$ to be the set of microgrids in a region
• Define a binary operation, union, that results in a microgrid
  – A union of two microgrids is itself a microgrid
  – The operation is associative
• This meets the definition of an associative magma, or semigroup
• But we must have self-management of the union, that is, The union of two microgrids permits self-management
• Coordination again
To move to a formal [open set] topology, we need to define intersection that maps to the set

- Is the intersection of two microgrids a microgrid?

A microgrid may participate in more than one higher level microgrid

- Structure can be described geographically, as we already define DR events to affect a county or region
- Intersection can allow us to disaggregate microgrids

Subset of a microgrid can be managed within, and coordinated with other components

Coordination again
What Do We Gain?

- A combination of microgrids is itself a microgrid
- Joining my office park’s microgrid $M_1$ with that of a nearby industrial park $M_2$ creates a new microgrid $M_3$
- Self-management of $M_3$ needs to take place
  - Coordination of behavior, inputs, and outputs supports self-management
- How do we coordinate?
What Makes a Microgrid Effective?

- A combination of two or more of energy
  - Storage
  - Generation
  - Consumption

- Goal is to permit
  - Reduction of net energy consumption
  - Reduction of cross-constituent microgrid communication & energy flow

- We’ll focus on cross-microgrid energy and coordination and ignore size
Well-behaved Grids...

- Provide better behavior to the Microgrids in which they participate
- Energy flows can be net, not separate
  - Regulation often distorts the electrical reality typically in the name of incentives
- Markets can be local to the microgrid for local interactions
- Combine microgrids by spanning markets and response
- Markets must be external to the microgrid for import/export interactions
• Collaborative energy interfaces and information exchanges with minimal information of the other side
• Transactive interactions to define local markets
• Use the terminology of markets and business
• Avoid the “knowledge problem” of more centralized management
• The simplest way to collaborate might be for one microgrid to control another (managed energy)
• But “simpler” actually means “more complex”
  – Does one controller understand the business needs of the constituent parts of the other microgrid?
  – The scope and number of devices or microgrids controlled can be very large
• Lessons from multi-tier applications in eCommerce
  – Use hierarchical structures to reduce complexity and performance bottlenecks
  – A simple structure can more easily be used effectively and realigned to changing business needs
These standards are in or approaching final status:

- **WS-Calendar** allows synchronization and common communication of schedules in a high level business manner

- **Energy Market Information Exchange** [EMIX] defines cross-cutting price and product definition communication for the Smart Grid

- **Energy Interoperation** defines DR, DER, and usage/demand projection and measurements and price+product distribution

All three are defined to, from, within, and outside of microgrids.

All drafts publicly visible
• Collaborative energy is the way to succeed
• View the constituents as independent entities who have agreed to collaborate
• Use open standards to connect and define markets and information exchanges
• Use Service-Oriented Architecture (SOA) to request service
• Compose security and reliability as indicated by business needs (See Security Section 5 in Energy Interoperation CSD)
What About Smart Microgrids?

- Smart Loads improve business value
  - Cox and Considine, Grid-Interop 2009
- Aggregation of fluctuating and partially balanced supply and demand has value
- Cross-microgrid interactions can be minimized
- Higher level microgrids coordinate more smooth demand and generation shapes
- Energy consumed and produced at a lower level / smaller microgrids, extra passed up the tree
Conclusions

• We have described
  – a topology of microgrids
  – Tools for assembling collaborative microgrids
  – Benefits of smoother and better managed loads
  – Reduction in complexity of managed and collaborative approaches
  – Simplified collaboration and management

• In the context of structured energy