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Structured Energy: Microgrids and Autonomous Transactive Operation

William Cox, PhD
Cox Software Architects LLC
Toby Considine
TC 9, Inc

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About William Cox

- Principal, Cox Software Architects LLC
- Consulting Software Architect
  - Complex systems, Service-Oriented Architectures, eBusiness/eGovernment, due diligence, …
  - Leader in NIST Smart Grid Framework & Roadmap
  - Member SGIP Smart Grid Architecture Committee
- Specializing in Collaborative Energy, Smart Grid architecture, interoperation, and information definition

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About Toby Considine

- President, TC9 Inc
- Strategic Technology consulting
  - Information and interaction standards for building design, operation, energy use (oBIX)
  - Strategic Technology Consulting in emerging markets and Venture Formation

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Outline

- Conclusions and Reference

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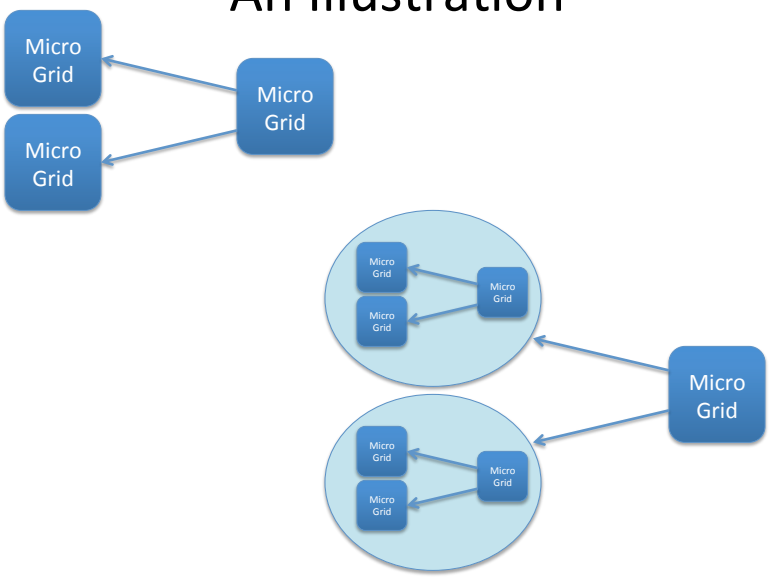
Introduction

- How do we assemble larger microgrids from smaller? Or decompose larger into smaller?
- What is a well-behaved microgrid?
- How do we collaborate across microgrids?
- We describe formal terminology for union and intersection and how to expand or narrow collaboration accordingly

Managed and Collaborative Energy

- Balance supply and demand
  - Managed Energy
    - Managed to different goals
    - Scale and control are issues
  - Collaborative Energy—*ask* versus *tell*
    - Choices consistent with business goals
    - Consider markets and requirements
- More information
  - **Smart Loads and Smart Grids—Creating the Smart Grid Business Case**, Grid-Interop 2009

An Illustration



An Illustration (2)

Microgrids (1)

- 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**

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

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Microgrids (2)

- A **microgrid** is a group of devices with self-management, and optionally
  - Storage,
  - Generation, and
  - Consumption of energy
- At least one is required
  - We describe the last two as “generation-only” and “consumption-only” microgrids

Microgrids (3)

- “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
  - 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

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**

Information within a Microgrid

- Information within a microgrid comes from
  - Other components
  - Aggregated or summarized by contained microgrid management
  - Markets (specific to the microgrid or external) for information sharing and coordination
    - Transactive energy, price-takers, semantics of price
  - Microgrids are the building block
    - Understanding Microgrids as the Essential Architecture of Smart Energy

A Semi-Group Under Union

- Take **M** to be a set of microgrids
  - 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

A Topology of Microgrids

- Consider the intersection of microgrids
  - To demonstrate a formal [open set] topology, we need to determine that finite intersection maps to the set
- A microgrid may participate in more than one higher level microgrid
  - Structure can be described geographically
  - DR events standardized to affect a feeder service area or a city/region
- Subset of a microgrid can be managed within, and coordinated with other components

What Do We Gain?

- A combination of microgrids is itself a microgrid
- Joining my office park's microgrid **M1** with that of a nearby industrial park **M2** creates a new microgrid **M3**
- Self-management of **M3** needs to take place
  - Coordination of behavior, inputs, and outputs supports self-management
- 2 or 3 microgrids?
- How do we coordinate?

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
- MicroMarkets scoped to each microgrid
- Combine microgrids by spanning markets and response

Structured Energy: Collaboration (1)

- 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

Structured Energy: Collaboration (2)

- Managed energy issues
  - Does the controller understand the business needs of the constituent parts or the other microgrid?
  - Number of devices/microgrids can be very large
- Lessons from multi-tier applications in eBusiness and the Internet
  - Hierarchical structures reduce complexity and performance bottlenecks
  - Simper structures more easily used and realigned to changing business needs

Structured Energy: Collaboration (3)

- 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

What About Smart Microgrids?

- Smart Loads improve business value
  - Cox & Considine, Creating the Smart Grid Business Case, Grid-Interop 2009
- Aggregation of fluctuating and partially balanced supply and demand has value
- Cross-microgrid interactions can be limited
- Higher level microgrids coordinate more smooth demand and generation shapes

Conclusions

- Microgrids form a topology over their components
- A model and tools for
  - Assembling microgrids
  - Disassembling microgrids
- Structured Energy permits taking advantage of smoother and better managed loads
  - Reduction in complexity of from managed to collaborative approaches
  - Simplified collaboration and management

References (1)

- Price and Product Definition
  - OASIS Energy Market Information Exchange (EMIX)
- Services and interaction
  - OASIS Energy Interoperation
  - OpenADR2 Profiles of Energy Interoperation
- Schedule
  - WS-Calendar extensions to iCalendar
  - PIM (abstract model) for WS-Calendar in progress

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References (2)

- Selected papers (most are linked from here)
  - Automated Transactive Energy (Cazalet Grid-Interop 2011)
  - Energy, Micromarkets, and Microgrids (Cox Grid-Interop 2011)
  - Applying Energy Interoperation and EMIX to DR and Transactive Energy (slides)(Holmberg Grid-Interop 2012)

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References (3)

- Energy Ecologies (Cox, Considine, Grid-Interop 2012)
- Understanding Microgrids as the Essential Architecture of Smart Energy (Considine, Cox, Cazalet, Grid-Interop 2012 Best Paper)