Microgrid Research Opportunities A look at the state of the art and what’s needed

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About General MicroGrids

- General MicroGrids, Inc is an international microgrid consultant and developer, working with governments, industrial customers and sustainable communities. We focus on renewable energy technologies and transformational microgrid construction.

- We chair the United Nation foundation microgrid workgroup for energy access in developing countries.

- Projects in east Africa, Asia and urban areas in North America.
Macro-level Energy Challenges

• Industrialized Countries
  – Reliability
  – Price
  – Integration

• Developing Countries
  – 5% - 15% Energy Access
  – Brittle Grid
  – Anchor Tenants
  – Subsidies
Industrialized Country Challenges

• Increased penetration of renewable energy into the generation mix
• Technology upgrades within the utility
• New systemic impact occurring behind the meter
• Distributed energy resources will likely become the normal state; how to integrate:
  – analog-centric power system
  – digital-centric information infrastructure
Developing Country Challenges

- Highly dependent upon fossil fuels
- Transmission between natural resources and cities
- Lack of capital for urban grid expansion
- Donor country funding for some infrastructure
- Non profit funding for small projects
- Lack of repeatable approaches
- Little or no regulatory support or investment incentives
State Of The Industry

- Distributed resources assembled over time
- Meets specific consumer or utility requirements
- No autonomy or distribution support
- Very little load–generation optimization
- Modest wholesale energy market support
- High engineering budgets
Current Technology Status

• State of the Practice
  – Component technologies in demonstration stage
  – Non-directional protection designed for on-grid operation

• State of the Art
  – Fundamental functions fulfilled with distributed architecture, but little coordination of components and microgrid level control
  – Microgrid system level control and protection functions being developed
  – Conventional distribution system protection which may not be valid in islanding operation mode
Sample Pilot Demonstrations

- ARRA – Interoperability and integration on system-wide scale
- Renewable and Distributed Systems Integration (RDSI): 15% peak load reduction using DER.
- KCP&L - “End to end” smart controls and communications systems monitor, manage and optimize distributed assets in real-time,
- Illinois Institute of Technology - “Perfect Power” system interconnects building integrated systems and builds redundancy into ComEd.
- SPIDERS and Post-Sandy Projects - Dynamic microgrids for energy surety and critical mission protection.
Federal programs, institutions, and the private sector are increasing microgrid development and deployment. The number of successfully deployed microgrids will verify the benefits and decrease implementation risks, further expanding the market for microgrids.
Microgrids For “Eco-cities”

• EU: NiceGrid (utility) and IssyGrid (city) projects to test DER new capabilities, economic, environmental and social impact
  – Interconnect communities with multiple tiers in a city’s grid plus link other resources (energy, transportation, data center, waste and water systems)

• Japan: Develop “Electricity Cluster-Oriented Networks”, a network of prosumers.
Remote Microgrid Pilots

- Kenya: 25 million population piloting village projects that are fuel-source opportunistic
- India: 300 million population piloting island, suburban and industrial locations
- Haiti: the island of 100+ pilots
- Alaska and Canada: many wind-diesel pilots
What is needed

• Distributed resources treated as an integrated and autonomous system
• Localized to a customer, community or region
• Smart grid applied towards balancing loads with renewable’s variable generation, storage
• Participate in distribution or transmission power, frequency and demand markets
• Treated as a unit, cluster, aggregate or market
Motivators

• Absence or occasional power
• Mixed utility integration (water, phone, gas)
• Rising grid energy costs
• Regional or national emission standards
• Expensive and delayed grid support
• Dispersed rural loads or supplies
• Reduced fuel consumption
Different than “the grid”

- Consumer engagement with resources to solve power issues locally
- High penetration of local renewables in residential, commercial, and industrial
- Not passive but active control in distribution
- Two-way power flow in distribution
- Distribution can become a transmission resource
- Components are part of a cohesive system – high dependency on standardization (physical and data)
Sustainable Energy for All

- UN Secretary-General Ban Ki-moon calls on governments, businesses, and civil society to make significant commitments to accomplish three objectives by 2030:

1. Ensure universal access to modern energy services.
2. Double the global rate of improvement in energy efficiency.
3. Double the share of renewable energy in the global energy mix.
A New Business Model

• Public Private Partnerships: ownership, development and operations
• Financial Structures: hybrid, off-grid and anticipated grid integration
• Load Growth: horizontal and vertical
• Capacity Building: training, education, economic growth
Microgrid Ownership Models

• Utility model – the distribution utility owns and manages the microgrid to reduce customer costs and provide special services (e.g. high power quality and reliability) to customers on the system.

• Landlord model – a single landlord installs a microgrid on-site and provides power and/or heat to tenants under a contractual lease agreement.

• Co-op model – multiple individuals or firms cooperatively own and manage a microgrid to serve their own electric and/or heating needs. Customers voluntarily join the microgrid and are served under contract.

• Customer-generator model – a single individual or firm owns and manages the system, serving the electric and/or heating needs of itself and its neighbors. Neighbors voluntarily join the microgrid and are served under contract.

• District Heating model – an independent firm owns and manages the microgrid and sells power and heat to multiple customers. Customers voluntarily join the microgrid and are served under contract.
Consumer owned Generation
Microgrid “Cells”

- Ideal for…
  - University Campus
  - Business Park
  - Indian Tribal Land
  - Municipality
  - Utility Distribution
  - Military Base

- Owned by…
  - Customer
  - Developer
  - Utility
  - Investment trusts

- Multiple microgrids will emerge locally
- Participate in grid and market support
- They will be aggregated
- They will be networked
- Transactive markets will emerge
- Individually, each may offer unique capabilities
- Central management will emerge
DER Integration
Networked MicroGrids

- Urban districts
- Villages
- Rural communities
- Campuses
Village Renewable Energy Microgrids
Considerations

- Resource integration
- Volt, VAR, variability (VVV) management
- Pricing and DR signal design
- Distribution controls – third party owners
- Sharing information in real-time (two-way)
- Market influences
- Communication and data security
- Standardization
Grid Modernization

Key Characteristics

• **Self-healing** - A grid able to rapidly detect, analyze, respond and restore from perturbations.

• **Empower and incorporate the consumer** - The ability to incorporate consumer equipment and behavior in the design and operation of the grid.

• **Tolerant of attack** - A grid that mitigates and stands resilient to physical and cyber security attacks.

• **Provides power quality needed by 21st century users** - A grid that provides a quality of power consistent with consumer and industry needs.

• **Accommodates a wide variety of generation options** - A grid that accommodates a wide variety of local and regional generation technologies (including green power).

• **Fully enables maturing electricity markets** - Allows competitive markets for those who want them.

• **Optimizes assets** - A grid that uses IT and monitoring to continually optimize its capital assets while minimizing operations and maintenance costs.
Technologies

• Grid-wide integrated communications
  – Internet for the power grid
• Sensing, metering, measurement
  – Digital two-way communication devices
  – Enable generation connect and disconnect
  – Enhance operator information
• Advanced control capabilities
  – Computer based grid monitoring
  – Enables dispatch of distributed resource
• Advance grid components
  – Energy storage
  – Distributed generation
• Decision Support
  – Analytics to guide grid operators
  – Semi-autonomous agent software
## Characteristics and Key Technologies

### Table of Characteristics and Key Technologies

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- ☮ = high influence
- ☮ = medium influence
- ☮ = low influence
Addressing Key Technology Gaps

- The difference between today’s grid characteristics and the Modern Grid characteristics.

- The difference between today’s key technologies and the key technologies needed for the Modern Grid.

- The difference between today’s RD&D and the RD&D of key technologies needed for the Modern Grid.

Programs

Desired Performance

Needed Technologies

Needed RD&D

- Performance Gap

- Technology Gap

- Research Gap
Gaps that remain in technology

Modernized utility
– Advanced communication
– Self healing distribution system
– Lots of sensors
– Automated control
– System Architecture
– Broadband where needed
– Multiple levels of control
– Sees into the customer’s systems
– Inexpensive, pervasive storage
Characteristics

– Low Power technology
– Standards-based hardware adapted to fit the problem resulting in lower overall cost
– Wireless infrastructure for monitoring and control
– Service architecture with three layers — Edgeware, Middleware and Centralware
– Open architecture for easy integration
– Plug-and-Play approach to the network installation.
– Reconfigurability — The capability of the technology to be reconfigurable allows OTA (over the air) upgrade of the firmware to be able to handle different and devices, applications, sensors, controllers, thermostats, etc.
R&D Planning

- Define an ideal microgrid architecture
- Transition an existing grid to achieve a better performing system that incorporates microgrids
- Expect remote microgrid to integrate either with other microgrids or “the grid”
- Define interfaces to reference existing and plan new standards
- Add intelligence and security in all elements of the system
US DOE Microgrid RD&D

To date, the bulk of work has been on microgrid demonstrations

FY 2013 and prior
- Renewable and Distributed Systems Integration
- Consortium for Electric Reliability Technology Solutions (CERTS)
- The Distributed Energy Resources Customer Adoption Model (DER-CAM)
- Energy Surety Microgrids
- Smart Power Infrastructure Demonstration for Energy, Reliability, and Security (SPIDERS)
- Standards Development – Interconnection and Interoperability

FY 2013 and beyond
- RD&D to reach 2020 microgrid performance targets* on costs, reliability, system energy efficiencies, and emissions

*Develop microgrid systems capable of reducing outage time of required loads by >98%; cost comparable to non-integrated baseline solutions (UPS + diesel genset); reduce emissions by >20%; improve system energy efficiencies by >20%
Microgrid Agent-Control System

- Add modern digital to legacy analog systems
- Orchestrate discrete DER with local grid and market-based distributed generation and demand response
- Arbitrate multiple microgrid cells for the benefit of grid stability
- Rules-based distributed intelligence
- Highly scalable, secure, adaptive and intelligent control system
Core behaviors inherited by all agents

- Built in support for policy based workflow orchestration which allows for configuring multiple operational criteria.
- Decision logic that incorporates analysis and response criteria based on electrical grid parametric models and rule based contingencies.
- Embedded behaviors for coordination with power analytics modules and grid protection schemes that manage grid reliability.
- Agent behaviors can be configured to operate autonomously (decisions are specific and local to the agent) or semi-autonomously (decision are collaborative towards achieving joint objectives with other agents).
- Agent control behavior implementations are based on real-time, deterministic domains (i.e. all actions have defined, bounded response times).
- Agent deployment and communications are performed using Smart Grid and Web Service standards (XML, SOAP, WSDL, UDDI, OpenADR, CIM).
Summary

• Economic, sociologic and environmental pressures require us to examine a new energy management model
• Distributed resources meet individual requirements and offer larger grid support
• MicroGrids allow generation, storage, and loads to operate autonomously, balancing out voltage and frequency issues
• MicroGrid cells are scalable and can be clustered locally as well as market opportunities
• MicroGrids are a new commercial growth area
• Competition will drive need for conforming architecture and standards
Recent IFC publication: “From Gap to Opportunity”

- Looks at all aspects of Energy Access: devices, microgrids and grid extension
- Outlines case studies of successful companies
- Provides wide range of reference materials
- Available for free download at www.ifc.org
Thank You

General MicroGrids

Balancing Energy for a smarter, renewable-driven grid

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