Opportunities in the Energy Industry - Microgrids

John Westerman, Vice President
What is a Microgrid?

“A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode.”

Microgrid Exchange Group, October 2010

There are federal and state incentives and tax credits for microgrids.
What to expect in the future

THE CASE FOR MICROGRIDS
From the 20th to the 21st Century

Generation
- 45%
- 17,342 units

Transmission
- 43%
- 164,000 miles

Distribution
- 34%
- 3 million mi

Consumer Systems
- <1%
- 12.3 M DG

- 25 M residential solar
- 1 M PHEV/PEV
- 10 M PHEV/PEV
- 50 M PHEV/PEV
- 2 M architectural wind
- 5 M building solar
- 100,000 Buildings as PP

- 500 wind parks
- 50 solar parks
- 5,000 distributed wind
- 5,000 utility solar

Continued increase in energy intensity

Prices increasing, in some regions faster than gasoline at the pump

Changeover to more and more digital loads

Consumer choices
Business As Usual Results

Source: EIA Electric Power Annual 2008
Design and engineering

CONSIDERATIONS
Why Microgrids?

- **Savings**: The microgrid portfolio of resources is tuned to the campus to provide economic savings.

- **Sustainability**: The microgrid portfolio enables a hedge against fuel cost increases.

- **Stewardship**: The microgrid enables deep penetration of renewables
  - Emissions reduction
  - Green marketing

- **Reliability**: The microgrid actively controls the network for better reliability.
Microgrids and the 5 Key Technology Areas

- **Advanced Control Methods**
- **Decision Support & Improved Interfaces**
- **Integrated Communications**
- **Advanced Components**
- **Sensors and Measurement**

*The Smart Grid is a System.*

Source: DOE/NREL Modern Grid Strategy
Microgrid Objectives

**Utility Network Management**

**Microgrid Objectives**
- Take action to improve reliability
- Take action to improve economics
- Take action to manage renewables

**Distributed Energy Resources**
- Utility-scale Energy Storage
- Rooftop PV Solar
- Micro-turbines
- Building Energy Storage
- Community Energy Storage
- Distributed Generation
- Home Energy System
- PHEVs
- Ground PV Solar Array

**Information**
- Electricity Pricing
- DER status
- Demand Response Programs
- Network status
- Community Objectives
- Load and Resource Profiles

**SCADA System**
- Capacitor Banks
- Voltage Regulators
- Automated Switches
- Power Electronics
- Communications

**Grid Resources**
- Microgrid Master Controller
## SDG&E Microgrid Overview

### Demonstration Project
- Contract with DOE (NETL) $12M
- Contract with California Energy Commission (CEC) $2.8M
- Duration: 3 years

### Site Selection
- Borrego Springs
- Circuit #170:
  - 4 MW peak demand
  - ~4 circuit miles.
  - ~3000 customers,
  - 560 kW PV (existing customer-owned)

### Microgrid Elements
- Distributed Generation
- Volt/VAR Management
- FAST*
- Advanced Energy Storage
- OMS/DMS Integration
- Price Driven Load Mgmt
- Customer DER Integration

### Microgrid Team
San Diego Gas & Electric, Horizon Energy Group, Oracle, IBM, Lockheed Martin, Motorola, Gridpoint, Xanthus Consulting, PNNL, USD

*Feeder Automation System Technologies
Project Location

Key Strengths:
• Potential to realize advanced reliability improvements
• High concentration of customer-owned solar
• Opportunity to develop self-sufficient circuit
• Great learning environment
• Extendable to service territory
Borrego Substation Circuit Diagram

Legend
- Existing
- MicroGrid
- SCADA Automated Switches
- Diesel Generator
- AES
- SCADA Controller on Capacitor
- SCADA Automated Switches

MG Area
- Residential Customer
- Residential Customer
- Residential Customer
- Residential Customer
- Thermostat
- PHEV
- Water Heater
- Pool Pump
- Gridpoint Connect
- Solar
- Storage
- AMI Meter
- HAN Device (ADM)
- Residential Customer
- Residential Customer
- Residential Customer
- Residential Customer
- Residential Customer

Borrego Substation
- C170
- C171
- C172
- SCADA

Industrial Customer
- PDLM
- Commercial Customer
- PDLM
- Residential Customer
- HAN
- Residential Customer
- HAN
- Residential Customer
- HAN
- Residential Customer
- HAN
MICROGRID USE CASES
Microgrid Architecture Overview

SCADA

DMS

MMC

MMC

MMC

MMC

Enterprise Bus

DG(s)

Energy Storage

PCS

Consumer DER

DR

PI ODS

Cap Banks

Switches

DNP-3 Serial

IP

High latency

Low latency

Historical Analysis

Horizon Energy Group
Microgrid Conceptual Architecture

Default assumption is that the microgrid will be controlled from Dist Ops. The system could be accessed by any properly configured client device for remote access.

GridPoint Data Center

- GPOC
  - Manages all customer DER / DR
  - Alternate Wireless link to home for GridPoint DER / DR Control

Motorola Network

- Internet
  - Communication with gridpoint SPOC and home DER / DR control

Customer Premise

- HAN
  - Customer premise DER / DR controlled via HAN. Communication to GPOC via Motorola wireless or customer ISP. Customer premise has optional solar and storage devices

Distribution Circuits – 170, 171, 172

Dist Ops

SEu Data Center

- DMS
  - Provides overall microgrid supervision and mediates MMC requests for switching
  - Provides EMS and DER/DR management for the microgrid

SEu Integration Bus(es)

AMI

EDW

SCADA

MMC

CBM

Provided communication to SDGE DER resources

Borrego Substation

Location of SDGE-owned generation, AES resources, and synchronizing relaying controlling island reconnect

Transmission

Horizon Energy Group
Functional Description (Use Cases)

- Utility Manages Utility-Owned Distributed Generation
- Real-time VAR Support
- Power System Automatically Reconfigures for Reliability using FAST
- Independent Energy Storage Operations
- Directed Energy Storage Operations
- MMC monitors grid system status and exerts control to maintain system stability and prevent overloads
- MMC monitors grid system status and passes information along to DMS
- MMC curtails customer load for grid management due to forecast
- MMC curtails customer load for grid management due to unforeseen events
- Planners Perform Analyses Using Multiple Data Sources
Microgrid Use Cases

- **Manage Local Grid System**
  - 2. Real time VAR Support
  - 3. Power System Automatically Reconfigures for Reliability using FAST (or MMC)
  - 6. MMC monitors grid system status and exerts control to maintain system stability and prevent overloads

- **Manage Utility DER**
  - 1. Utility Manages Utility-Owned Distributed Generation
  - 4. Independent Energy Storage Operations

- **Manage Customer Load**
  - 5. Directed Energy Storage Operations
  - 8. MMC curtails customer load for grid management due to forecast
  - 9. MMC curtails customer load for grid management due to unforeseen events

- **Manage Solar**
  - 10. Load Researchers and Planners Perform Analyses Using AMI Data
Example: Sparx EA Business Process Diagrams

Use Case 4.2: Independent Energy Storage Operations

BPMN Scenario 4.2: Execute charge/discharge in load following mode

1. **AES Independent Mode Desired**
   - **Direct AES Mode of Operation**
   - **Send voltage status**
   - **DMS Monitors status of microgrid**

2. **MMC Monitors health and status of DG MicroGrid Resources**
   - **Compare voltage status**
   - **Permit continued regulation or take corrective action**
   - **Notify of change in status**

3. **Monitor local circuit voltage and react automatically**
   - **PCS continues operator or responds to MMC corrective action plan**
   - **Notify of change in status**

**End**
MICROGRID MASTER CONTROLLER DESIGN
Active Monitor and Control

• Optimize variable aspects: load, wind, solar, storage
• Continuously monitor and trend health of all system components
• Base the energy market purchases and sales on hourly forecasts
• Leverage resources into the energy market on local non-peak days
• Island (i.e. disconnected or zero net electric import) when needed or advantageous
Successful Microgrid Design

Integrate
Understand
Optimize
Act
Interface

Physical devices / resources

See
NOC Dashboard Website
MMC – Two Designs

MMC Brain

Integrate
Understand
Optimize
Act
Interface
See

Agent Community

Integrate
Understand
Optimize
Act
Interface
See

Optimize
Act
Interface

Optimize
Act
Interface

Optimize
Act
Interface

Optimize
Act
Interface

Horizon Energy Group
MMC Design - Embedded

- There are several key elements embedded in multiple areas of the design
  - Interoperability standards
  - Common information model
  - Cyber security
  - Service-oriented architecture
Algorithm Map

Integrate

Understand

Optimize

Act

Interface

See
DG Start Sequence

MMC Request Start

Operator Authorizes Operation

Safety Check and Synchronization

Local DG Controls
MICROGRID MARKETPLACE
North American Microgrid Market 2015

Source: Pike Research
Market Size

Microgrid Capacity, World Markets: 2010-2015

Source: Pike Research

2,000 US microgrids by 2015
- Pike Research, Dec 2009

~$2B annual US market by 2015
- Pike Research, Dec 2009
PROPOSED PROJECT

1.5 MW average demand
750,000 sq ft
3,200 engineers
Executive Summary

- Microgrid – sustainable, reliable active 24/7 control of supply and load
- Sustainability Objectives
  - Reduce annual energy cost by 15% for the long-term
  - Reduce carbon footprint by 18,750 Tons over 10 yrs
  - Increase reliability and reduce the risk of an outage
  - Sustainability leadership among peers
- Not replacing the utility grid (still connected), but replacing much of the utility supply to be more cost effective & reliable
- Increase “green energy” capacity from 0% to 100%
  - Tremendous green marketing opportunity
  - LEED Certification
  - Following the White House call for 25% renewables in the federal sector
### Resources Modeled

<table>
<thead>
<tr>
<th>Resource</th>
<th>Capacity (kW)</th>
<th>Hours / Year</th>
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<tbody>
<tr>
<td>PV</td>
<td>1369</td>
<td>1579</td>
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<tr>
<td>Wind</td>
<td>102</td>
<td>5840</td>
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<td>DG Base</td>
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<td>2088</td>
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<td>200</td>
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<td>Fuel Cell</td>
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<td>8322</td>
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<tr>
<td>Energy Storage</td>
<td>422</td>
<td>1564</td>
</tr>
</tbody>
</table>

Horizon has also modeled a 11,200 ft² Solar Thermal system to offset space and water heating. This would be co-located with the roof PV arrays.
Keys to Success

• Portfolio mix of resources (high level of renewables)
• ISO-NE DR market participant
• Integration of resources
• Gaining approval for State and Utility Incentives
• MMC Control to optimize operations (economics, reliability, and environmental considerations)
The Project

- Estimated $5.33M total development cost after incentives and tax credits
  - Before Incentives and Tax Credits: $11.39M
  - Equity: $0.40M
  - Total Incentives: $6.06M
    - Federal ITC: $2.11M
    - State Incentives: $3.32M
    - Utility Incentives: $0.63M
  - Financing: $6.22M @ 3.25%
Where does the microgrid revolution lead?

CONCLUSIONS
Rate Comparison – Avg Utility vs Microgrid

Commercial Electric Rate Breakdown
(Average Utility vs Microgrid)

- Avg Util data is based on EIA Electric Power Annual 2008, published Jan 2010
- Microgrid data is based on Horizon microgrid model of typical Smart Grid 2020 City
Emerging Design Elements

• State estimation (day ahead)
• State measurement (real-time)
• Economic, reliability, environment (ERE) dispatch tools
• Objective functions and algorithms for most of the design (Design Overview)
• Anticipatory and response/corrective algorithms
• Energy arbitrage algorithms
• MMC – enterprise vs distributed; brain vs agent community
Microgrid Future Vision

- RTO / ISO Market
- Utility X Control Area
- SCADA
- MMC
- Apps
- DER LAN / Integration Bus
- Community / Campus
- Microgrid NOC
- Other microgrids

Horizon Energy Group
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*Horizon Energy Group is a key contractor on the DOE Smart Grid Implementation Strategy Team*

*Horizon Energy Group Principals are Certified Navigators for Carnegie Mellon’s Software Engineering Institute’s Smart Grid Maturity Model*

*Horizon Energy Group named in 2008 as a Company to Watch in the book, “Perfect Power” by former Motorola Chairman, Bob Galvin, and former EPRI CEO, Kurt Yeager.*

*Horizon listed in 2009 as one of the “Top 100 Movers and Shakers in the Smart Grid Movement” by GreenTech Media.*