INNOVATIVE BUSINESS CASES FOR THE DEPLOYMENT OF MICROGRIDS

FEATUREING

Ken Dulaney, FREEDM Systems Center
Nathan Adams, ABB
Jim Musilek, NC Electric Cooperatives
Kevin Meagher, Power Analytics

2017 State Energy Conference of North Carolina
Solutions for a diverse energy economy
What is FREEDM?

- Future Renewable Electric Energy Delivery and Management Systems Center
- Application to National Science Foundation in 2007 for Engineering Research Center
- Grand Challenge to Modernize the Distribution Grid
FREEDM in one Diagram

Power Systems

Power Electronics

Information Technology

We are here!
University Partners

NC State University

Missouri S&T

Arizona State University

Florida State University

ETH

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

RWTH Aachen University
Industry Members

**Full (5):**

- ABB
- Duke Energy
- Itron
- NY Power Authority
- TOTAL

**Associate (16):**

- FPL
- Eaton
- Schneider Electric
- Edison
- Pos-En
- Cree
- LORD
- Fuji Electric
- Sensus
- Hitachi
- Weidmann
- Toshiba
- Huawei
- EPRl
- Mitsubishi
- Toyota

**Affiliate (5):**

- North Carolina’s Electric Cooperatives
- Green Energy Corp
- AV
- Triangle MicroWorks, Inc.
A network of distributed energy resources utilizing secure communications for intelligent power management enabled through advances in power electronics.
A microgrid is a localized grouping of electricity sources and loads that normally operates connected to and synchronous with the traditional centralized grid (macrogrid), but can disconnect and function autonomously as physical and/or economic conditions dictate.
Utility Trends: Microgrids

Source: US DOE Website, Sept. 2015
Panelists

Jim Musilek, NCEMC
Steve Lopiano, Power Analytics
Nathan Adams, ABB
POWERING EVERYDAY LIFE FOR 2.5 MILLION

24% of the population

45% of the land mass

Member-owned and governed
Electric co-ops are private, not-for-profit utilities owned by the people they serve. Members democratically elect a board of directors to represent their interests and conduct cooperative business.

Not for profit
Co-ops exist to serve their members and communities. We provide electricity at cost, not for a profit. Revenue collected in excess of expenses is given back to members in the form of capital credits.

Committed to community
Keeping the lights on. Recruiting new industry. Educating the leaders of tomorrow. Electric co-ops take seriously our responsibility to improve lives in our communities.

BILLION
in poles, wires, substations and other infrastructure

HUNDRED
employees at the 26 co-ops across the state

MILLION
in payroll and benefits for thousands of families

MILLION
paid in taxes to support North Carolina communities

THOUSAND
miles of line connecting rural and suburban North Carolina
Community Solar Projects
Utility Scale Solar Projects
Microgrid and Storage Projects
Energy Efficiency Projects
What is a Microgrid?

US Department of Energy Microgrid Exchange Group Definition:

- “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”
Why are Microgrids Interesting?

Interest in off-grid or microgrid for:

1. Deployment of renewables (with improving economics of PV)
2. Local recovery of heat (from CHP)
3. Local resiliency (bringing generation closer to end use, reducing exposures in power delivery)
NCEMC Microgrid Project

Ocracoke Island Microgrid

- **Battery Storage**
  - Owned by NCEMC
  - Installed at Ocracoke Generator

- **Solar Array**
  - Owned by NCEMC
  - Installed on roof of Ocracoke Generator

- **Thermostats**
  - 175 thermostats distributed
  - Targeting 300 – 500 total

- **Smart Water Heater controls**
  - 30-50 units distributed
A Utility Microgrid

Member-Consumers

Ocracoke Island

Microgrid Controller

Operations Center

NCEMC

Ecobee

Carina

200+ Thermostats
50 Water Heater Controls

3 MW Diesel Generator
500 kW / 1 MWh Tesla Battery Storage
15 kW Rooftop Solar

NC Electric Cooperatives
Demand Response Performance

Ocracoke Microgrid
10 February 2017

Integrated kWh

<table>
<thead>
<tr>
<th>Load and Resources (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Load</td>
</tr>
<tr>
<td>HE 7</td>
</tr>
<tr>
<td>HE 8</td>
</tr>
<tr>
<td>HE 9</td>
</tr>
</tbody>
</table>

- Thermostats (est)
- TESLA_1(kW)
- TESLA_2(kW)
- Solar (est)
- Island Net Load
- Total Load
NCEMC Consumer Microgrid Project

Agribusiness

- **Battery Storage**
  - 250 kW – 750 kWh Samsung / PowerSecure system
  - Owned by NCEMC
  - Installed on member’s farm

- **Existing on-site generation owned by member**
  - Bio-gas generator
  - Solar
  - Conventional diesel
NCEMC Consumer Microgrid Project

Why Agribusiness?
- Key to rural economies
- Active members of the cooperative family
- Environmentally-focused
- Existing investments in distributed energy

Benefits of this Microgrid
- Shared benefit to the portfolio
- Increased renewable resource
- Improved community reliability
A Consumer Microgrid

- Reclosers and Sectionalizers
- Battery storage
- Bio-gas generator
- Solar
- Conventional diesel generator

Microgrid Controller

Operations Center

NCEMC
Innovative Business Cases for the Deployment of Microgrids
Observations

• **Maximization and use of existing infrastructure**
  
  Existing systems (BMS, SCADA, Communications) will play a role in the operation of the system and must be including the process from day 1.

• **Engaging assets beyond mission critical**
  
  Economic value of the assets (generation and load) and the ability to use those assets without compromising the mission.

• **Visibility**
  
  Projects must be clear to stakeholders and engage the community of participants.
Power Analytics Approach

Energy Alignment Plan™ (EAP)

• A process that uses proprietary Power Analytics Software to align the economic and power modeling objectives of the customer
Aligned Projects

Naval Base San Diego

NY REV Phase 1 & Phase 2

Panama Solar
Building a Case for Grid Tied Microgrids

Nathan Adams, Director, Technology and Business Development
## ABB Microgrids and Renewable Automation

Experts in microgrid system control and stabilization

<table>
<thead>
<tr>
<th>Hybrid Renewable Microgrid</th>
<th>Renewable Integration and Optimization</th>
<th>Ancillary power system services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marble Bar (solar/diesel)</td>
<td>Marsabit (Wind/Diesel Off-grid System)</td>
<td>SP Ausnet (GESS)</td>
</tr>
<tr>
<td>Hopetoun (wind/diesel)</td>
<td>Sandfire Degrussa (PV/diesel)</td>
<td>Lanzarote (grid stabilizing system)</td>
</tr>
<tr>
<td>Coral Bay (wind/diesel)</td>
<td>Laing O'Rourke (solar/diesel)</td>
<td>Kodiak Island (grid stabilizing system)</td>
</tr>
<tr>
<td>Bremer Bay (wind/diesel)</td>
<td>Gorona del Viento (wind/pumped-hydro/diesel)</td>
<td>La Gomera (grid stabilizing system)</td>
</tr>
<tr>
<td>Cocos (Keeling) Island (wind/diesel)</td>
<td>Ross Island (wind/diesel)</td>
<td>Leinster Mine (peak lopping)</td>
</tr>
<tr>
<td>Denham (wind/diesel)</td>
<td>Rottnest (wind/diesel)</td>
<td>Alinta Mine (Spinning reserve)</td>
</tr>
<tr>
<td>Esperence (wind/diesel)</td>
<td>Mawson (wind/diesel)</td>
<td></td>
</tr>
<tr>
<td>WEB Aruba (wind/solar/diesel)</td>
<td>Robben Island (Solar/battery/diesel)</td>
<td></td>
</tr>
<tr>
<td>Longmeadow (solar/diesel/battery)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Reference

- Marble Bar (solar/diesel)
- Hopetoun (wind/diesel)
- Coral Bay (wind/diesel)
- Bremer Bay (wind/diesel)
- Cocos (Keeling) Island (wind/diesel)
- Denham (wind/diesel)
- Esperence (wind/diesel)
- WEB Aruba (wind/solar/diesel)
- Longmeadow (solar/diesel/battery)
- Sandfire Degrussa (PV/diesel)
- Laing O'Rourke (solar/diesel)
- Gorona del Viento (wind/pumped-hydro/diesel)
- Ross Island (wind/diesel)
- Rottnest (wind/diesel)
- Mawson (wind/diesel)
- Robben Island (Solar/battery/diesel)
- Marsabit (Wind/Diesel Off-grid System)
- PINE GAP (Battery Energy Storage System)
- Legion (Biogas/battery system)
- Chugach (Wind/Flywheel/ battery)
- Carnegie (wave)
- Kalbarri (wind)
- Falal (wind/diesel)
- Chitose (Solar/diesel)
- SP Ausnet (GESS)
- Lanzarote (grid stabilizing system)
- Kodiak Island (grid stabilizing system)
- La Gomera (grid stabilizing system)
- Leinster Mine (peak lopping)
- Alinta Mine (Spinning reserve)
Grid Connected Microgrid Key Applications

1. End of line applications
2. Storm resiliency
3. Reliability requirements
4. Grid/commodity independence
5. Leverage existing DG
6. Defer/Offset T&D upgrades
Understand your objectives and your resources first

Key Questions:
What are the goals of your microgrid?
– Reliability: Islanding duration and frequency
– Sensitivity: Transition requirements
– Independence: Commodity exposure
– Carbon: Renewable content
– Cost: LCOE

What are the characteristics of your site?
– Load sensitivity
– Space available
– Resources available
– Distribution network structure

Generation/storage mix and dimensions should be tailored once the above are understood
## Comparison of microgrid generating technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reciprocating engine</td>
<td>• Low up front cost</td>
<td>• Noise/emissions</td>
</tr>
<tr>
<td></td>
<td>• Load following flexibility</td>
<td>• Fuel supply requirements</td>
</tr>
<tr>
<td></td>
<td>• High power density</td>
<td>• Maintenance requirements/costs</td>
</tr>
<tr>
<td>Fuel cell</td>
<td>• High power density</td>
<td>• Limited load following flexibility</td>
</tr>
<tr>
<td></td>
<td>• Quiet operation</td>
<td>• High up front cost</td>
</tr>
<tr>
<td>Microturbine</td>
<td>• High power density</td>
<td>• Limited load following flexibility</td>
</tr>
<tr>
<td></td>
<td>• Quiet operation</td>
<td>• High up front cost</td>
</tr>
<tr>
<td>Combined Heat &amp; Power (CHP)</td>
<td>• Efficient use of waste heat</td>
<td>• Requires thermal customer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• May have limited flexibility</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• High up front cost</td>
</tr>
<tr>
<td>Wind</td>
<td>• No fuel costs</td>
<td>• Intermittent generation</td>
</tr>
<tr>
<td></td>
<td>• Renewable</td>
<td>• Low power density</td>
</tr>
<tr>
<td>Solar</td>
<td>• No fuel costs</td>
<td>• Intermittent generation</td>
</tr>
<tr>
<td></td>
<td>• Renewable</td>
<td>• Low power density</td>
</tr>
</tbody>
</table>
How much does a microgrid cost?

It Depends...

Every project is different. Project cost depend on:

– Size of microgrid
– Asset selection
– Presence of existing assets
– Distribution configuration requirements
– Load sensitivity
– Load control opportunities

What is a useful metric? LCOE, Capital Cost, Net Present Value?
## Typical cost ranges for microgrid assets

<table>
<thead>
<tr>
<th>Technology</th>
<th>Cost Range</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reciprocating engine ($/kW)</td>
<td>$450 - $700</td>
<td>• Natural gas fired reciprocating engines often priced at a premium to diesel</td>
</tr>
<tr>
<td>Fuel cell ($/kW)</td>
<td>$7,000 - $10,000</td>
<td></td>
</tr>
<tr>
<td>Microturbine</td>
<td>$1,000 - $1,500</td>
<td></td>
</tr>
<tr>
<td>Combined Heat &amp; Power (CHP)</td>
<td>Highly variable</td>
<td>• Costing hard to define and is greatly impacted by size/complexity.</td>
</tr>
<tr>
<td>Wind ($/kW)</td>
<td>$2000 - $5000</td>
<td>• Smaller turbines higher in cost per kW</td>
</tr>
<tr>
<td>Solar ($/kW)</td>
<td>$1,600 - $2,500</td>
<td>• Cost driven by size of installation</td>
</tr>
<tr>
<td>Battery storage ($/kWh)</td>
<td>$500 - $1,000</td>
<td>• Battery sizing drives costing</td>
</tr>
<tr>
<td>Thermal Storage ($/kWh)</td>
<td>$0 - $500</td>
<td>• Ice storage, ceramic or liquid heat storage</td>
</tr>
<tr>
<td>Controllable Load</td>
<td>Opportunity cost</td>
<td>• Typically the most cost effective resource</td>
</tr>
<tr>
<td>Microgrid controls (Total $)</td>
<td>$100K - &gt;$1M</td>
<td>• Large variation in cost by project</td>
</tr>
<tr>
<td>Balance Of Plant (BOP) (Total $)</td>
<td>$0 - &gt;$1M</td>
<td>• Depends on need for reconfiguration of distribution system</td>
</tr>
</tbody>
</table>

Source: ABB estimates and industry publications
## How do you make the business case?

**Value stacking**

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
<th>Potential value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy margin</td>
<td>Profit gained from sale of power</td>
<td>Low - medium</td>
</tr>
<tr>
<td>Outage reduction</td>
<td>Reduced customer cost of outage</td>
<td>Low to very high</td>
</tr>
<tr>
<td>T&amp;D offset</td>
<td>Deferral or offset of utility T&amp;D upgrades</td>
<td>High</td>
</tr>
<tr>
<td>Peak load management</td>
<td>Local, system or market peak reduction value</td>
<td>Medium</td>
</tr>
<tr>
<td>Arbitrage</td>
<td>Using battery to buy low/sell high</td>
<td>Low</td>
</tr>
<tr>
<td>Ancillary services</td>
<td>Frequency regulation, spinning reserve, renewable integration and others</td>
<td>Medium - high</td>
</tr>
<tr>
<td>Reduced utility truck roles</td>
<td>Major storm crew efforts can focus on non-microgrid areas</td>
<td>Low</td>
</tr>
</tbody>
</table>

Value stacking requires appropriate enabling software and controls.
Longmeadow Microgrid Project

South Africa
Longmeadow microgrid pilot project

Background

- Energy demand at Longmeadow has been relatively constant over the last four years. However, due to the country energy crisis, energy costs are increasing steadily.

- Due to rising demand and insufficient generation capacity, utilities are capping power consumption or imposing high demand charges.

- Nonetheless, grid outages have been increasing in South Africa and the reliance on backup diesel generators has increased energy cost for the Longmeadow plant.

- This situation is common across Africa as well as numerous other countries where utilities are not able to meet rising load demand with infrastructure development.

- The market is looking for innovative solutions which would guarantee a reliable access to electricity while reducing electricity costs.

ABB has deployed in its facility in Longmeadow, South Africa an innovative microgrid project that solves these challenges.
Longmeadow microgrid project

Concept

- **Rooftop PV** reduces consumption of:
  - Eskom grid electricity
  - Diesel fuel

- **PowerStore-Battery** ensures:
  - Smooth transition during outages
  - Peak lopping during peak consumption times
  - PV energy shifting to peak production times
  - Optimal operating conditions for diesel gensets

- **Microgrid Plus System** enables:
  - Microgrid energy management

Outcomes: Reliable Electricity, Energy Independence, Renewable Energy Integration
Longmeadow microgrid project

Project specifications

- **Rooftop PV**: 750 kW solar plus ABB PVS800 inverter station
- **Storage**: ABB 1.3MW PowerStore battery system, 380 kWh Samsung lithium ion
- **Control System**: ABB Microgrid Plus control system

Optimally dimensioned system for reliable performance and maximized returns
The Business Case for Longmeadow

Value Stacking

- Microgrid Capex/Opex
- Avoided Diesel
- Peak Shaving
- Avoided Production Loss
- Power Factor Correction
- Solar kWh

NPV Positive
End of line application / Deferred T&D upgrades

SP AusNet grid energy storage system
End of line industrial development served by radial feeder ~1 MW

Multi km feeder line with frequent reliability issues (brush fires)

Looping and rebuild options expensive and difficult to permit

Expected growth in customer load requires peak shaving
SP Ausnet

Solution

- Fully portable
- 1MW/1MWh PowerStore BESS
- 1 MW Diesel Genset
- Ring Main Unit substation/switchgear
The Business Case for SP Ausnet

Value Stacking

- Microgrid Capex/Opex
- Ancillary Services
- T&D Deferral

NPV Positive
Q&A and Contact information

If you have questions, please contact me further

Speakers

Nathan Adams
- ABB
- 919-376-5884
- nathan.adams@us.abb.com