Introduction to Microgrids & Control Solutions
Industry Perspective on Microgrid

Q. Will microgrids reduce utility load in the future?
- Yes, but not materially: 45%
- Yes, significantly: 47%
- No, not at all: 8%

Q. In the future, who do you think should be the dominant owner/operator of microgrids?
- Partnerships of below parties: 43%
- Utility: 31%
- Non-utility/private company: 16%
- Public (municipality, military, etc): 8%
- University: 2%

Q. When do you expect non-utility entities in your service territory to develop microgrids?
- They are already doing so: 33%
- 1-5 years: 27%
- 5-10 years: 17%
- Over 10 years: 8%
- Never: 2%
- Don't know: 13%

Q. When will microgrids become a viable business opportunity for utilities?
- Today: 19%
- 1-5 years: 37%
- 5-10 years: 31%
- Over 10 years: 10%
- Never: 3%

Unrestricted © Siemens AG 2016
Page 2
Microgrid Market Potential to Exceed $670 Million

Take Away
- A five increase from 2014 ($133 million) to 2017 ($671 million)
- Project cost $/kW to decrease by cost efficiency gains in controller development and project development
- Beside generation vendors, the biggest opportunities will be controller, modeling and switching providers

Source: GTM Research 2014
Consumers Initiatives towards Microgrid and More

9 Massive US Companies Pledge To GO 100% Renewable

- Goldman Sachs (2020)
- Johnson & Johnson (2050)
- Nike (2025)
- Procter & Gamble
- Salesforce
- Starbucks
- Steelcase
- Walmart
Microgrid Definition

- Scaled-down power system
- Local generation and consumption of power
- Typically connected with main grid via coupling point
- Manage decentralized energy, including renewables & storage, in a local environment
- Allow for optimizing controllable loads and building automation
Three Pillars of a Microgrid System

**Mixed Generation Assets**
- Wind, Solar, other RES
- GT, ST, CHP, Fuel Cell, Diesel Gen-sets
- Battery, UPS, Other ESS

**Complicated Load Profile**
- Critical vs. Non-Critical
- Controllable vs. Non-Controllable
- Sheddable vs. Non-Sheddable

**Complex Modes of Operations**
- Grid-Connected vs. Off-Grid
- Black start
- Re-synchronization to the Grid
Role of a Microgrid Controller

Components (SW and HW):
- **Field layer**
  - DG: Solar PV, Wind turbine, combustion engine, CHP, CCHP
  - Energy Storage: Battery, ultra capacitor, flywheel, E-car
  - Grid components: switchgear, distribution line, transformer, protection
  - Power consumer mgmt.

- **System layer**
  - Power electronics: Smart inverter, smart connection
  - Smart controller (DG, storage, loads)

- **Communication layer**
  - IT-communication
  - Smart meters, sensors

- **Control & supervisory**
  - Central mgmt. & control comp.
  - Operation tool for baselining & decision logic (e.g. weatherforecast)

- **Monitor and Control all Assets:** SCADA
- **Balance Supply and Demand:** Frequency Control
- **Manage Sufficient and Safe Voltage:** Voltage Control
- **Energy Management:** Scheduling Generation & Storage
- **Transition between Island and Grid-connected States**
- **Manage a Black Out Situation:** Black Start Restoration
- **Respond to Utility’s Demand Response Request**
- **Optimize the Microgrid for Maximum Asset Utilization**

Unrestricted © Siemens AG 2016
Page 7
Microgrid Control Hierarchy

Tertiary Control

- Energy Trading
- Load Forecasting
- Load Management
- Generation Forecasting
- Generation Optimization
- Power Quality Analyzer

Secondary Control

- SCADA
- Archiving
- Frequency Regulation
- Voltage Regulation
- Emergency Demand Response
- Power Quality
- Protocol Conversion
- Automatic Islanding & Resynchronization

Primary Power System Equipment

- Coupling Switch
- Breakers
- Relays/Meters
- OLTC
- Primary Controller

Distributed Energy Resources

- PV
- Diesel
- Fuel Cell
- EVFMS
- Energy Storage
- Building Mgmt

Key:

- Advanced Functions
- SCADA
- Secondary Control
- Local Control

 MGMS
Less Fast

Power Automation Systems
Fast

Local Control
Very Fast
Microgrid Control Hierarchy – Local Control

Primary Power System Equipment

Switch/Circuit Breakers
Protection and Control Devices and Power Meters
On-load Tap Changer Controller
Genset Controller

Primary Power System Equipment
- Coupling Switch
- Breakers
- Relays/Meters
- OLTC
- Primary Controller

Distributed Energy Resources
- PV
- Diesel
- Fuel Cell
- EVFMS
- Energy Storage
- Building Mgmt

Key:
- Local Control
Microgrid Control Hierarchy – Local Control

Distributed Energy Resources

- PV Cells / Solar Inverter
- Diesel Generators
- Fuel Cells
- Energy Storage (Batteries)
- Building Management System

Primary Power System Equipment

- Coupling Switch
- Breakers
- Relays/Meters
- OLTC
- Primary Controller

Distributed Energy Resources

- PV
- Diesel
- Fuel Cell
- EVFMS
- Energy Storage
- Building Mgmt

Key: Local Control
Microgrid Control Hierarchy – Secondary Control

Key:
- Automatic Islanding & Resynchronization
- Emergency Demand Response
- Power Quality
- Protocol Conversion
Microgrid Control Hierarchy – Secondary Control

**Secondary Control**

- Engineering and Maintenance Station
- Redundant SCADA Servers
- Control Room
- Interface to Building Automation System
- TCP/IP Modbus / IEC 61850

**Key:**
- Automatic Islanding & Resynchronization
- Emergency Demand Response
- Power Quality
- Protocol Conversion

Unrestricted © Siemens AG 2016
Page 13
IEEE States:

“Power quality is the concept of powering and grounding sensitive equipment in a matter that is suitable to the operation of that equipment “.

The need for Quality Power - Every market is exposed by financial losses due to power availability and voltage quality. Minimizing losses due to power quality issues starts in identifying and understanding the problem.

Power reliability is truly a business and operations issue rather than merely an inconvenience.
Microgrid Control Hierarchy – Power Quality

Power Quality

Electrical System

- Harmonics
- Reactive Power
- Flicker
- Unbalance

Loses

Electrical System

- Harmonic Predistortion
- Voltage Dips / Swells
- Voltage Variations
- Interruption

Loses
Microgrid Control Hierarchy – Power Quality

Office Level (Analysis)
- One Location for all Power Quality Data
- Both Quick and Detailed Review of your Power Quality Analysis and Reports

Substation Level (Archiving)
- Fault records
- Power Quality data
- PDR records
- Topological Information
- Evaluation results
- Fault location reports
- Scheduled reports

Process Level (Recording)
- IEC61850
- Profibus FMS
- Modbus
- Profibus DP
- Autom. COMTRADE Import
- Autom. PQ Diff Import

Power Automation Services
- Fault location
- Grid Code evaluation
- Creating scheduled Reports
- Notification via E-Mail & SMS
- COMTRADE / PQ Diff Export
- Report Export

PQ Recorder
- Snapshot of Disturbances

Protection devices
- Fault recorder
- PQ Recorder
- Power Meter

Unrestricted © Siemens AG 2016
Page 17
Typical Design Example

12kV Underground Feeder

Renewable Generation

Energy Storage

Critical Loads

Utility Service

Point of Common Coupling to Grid

Dispatchable Generation

MCL #1

MCL #2

MCL #3

1000 kW Generator

New ATS

Switch

Existing ATS

Switch

Fuel Cell

PV

Battery

UPS

UPS

PCC Recloser
Microgrid Control Hierarchy

Tertiary Control
- Energy Trading
- Load Management
- Power Quality Analyzer
- Load Forecast
- Generation Forecast
- Generation Optimization

Secondary Control
- SCADA
- Archiving
- Frequency Regulation
- Voltage Regulation
- Automatic Islanding & Resynchronization
- Emergency Demand Response
- Power Quality
- Protocol Conversion

Primary Power System Equipment
- Coupling Switch
- Breakers
- Relays/Meters
- OLTC

Distributed Energy Resources
- PV
- Diesel
- Fuel Cell
- EVFMS
- Energy Storage
- Building Mgmt

Key:
- Advanced Functions
- SCADA
- Secondary Control
- Local Control

MGMS
- Less Fast

Power Automation Systems
- Fast

Local Control
- Very Fast
Microgrid Control Solutions

Monitor
- Grid health
- Fast detection of grid failure
- Power quality, freq/ voltage
- Alarming
- ...

Control
- Freq/Volt control
- Reserve management
- Fast grid restoration
- Black start sequence
- Load and generation controls
- Fast Load shedding
- ...

Optimize
- Mode of operations
- Economic Dispatch
- “When to generate what and why” to provide secure power to mission critical loads
- ...

Unrestricted © Siemens AG 2016
Page 20
Advanced Microgrid Control Solutions

Min $\sum$ cost

-or-

Min $\sum$ emissions

Weather Data Feed → Load and Renewable Generation Forecast → Microgrid Optimization Module

Historical Load and Generation Data

Load and Generation Schedules

Feedback

Generation & Load Control

Control Commands
MGMS Overview
Day-ahead Forecast and Scheduling based on Optimization

Grid Expensive $$$
Discharge Storage
Charge Storage

Grid Cheap $
Discharge Storage
Charge Storage

Gas Generation Online

Grid Normal $$
Discharge Storage
Charge Storage

Grid Expensive $$$
Discharge Storage
Charge Storage

Grid Cheap $
Discharge Storage
Charge Storage

Unrestricted © Siemens AG 2016
Page 22
### Advanced Microgrid Control Solutions

<table>
<thead>
<tr>
<th>Reliable Power</th>
<th>Cost Savings</th>
<th>Security</th>
<th>Resiliency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliable</td>
<td>Efficient</td>
<td>Sustainable</td>
<td>Secure</td>
</tr>
<tr>
<td>• Alarming</td>
<td>• Optimal economic dispatch &amp; Unit commitment</td>
<td>• Emission Optimization</td>
<td>• Strong security, platform based on utility-level system</td>
</tr>
<tr>
<td>• Frequency Control</td>
<td>• Simple Deployment</td>
<td>• Solar &amp; wind forecasting</td>
<td>• Patch management</td>
</tr>
<tr>
<td>• Voltage Control</td>
<td>• Autonomous or Simple Operation</td>
<td>• Maximum penetration of renewables via storage optimization</td>
<td>• Security architecture &amp; design</td>
</tr>
<tr>
<td>• Reserve Management</td>
<td>• Demand Charge Management</td>
<td></td>
<td>• Cyber vulnerability assessment</td>
</tr>
<tr>
<td>• Grid to Island Transition</td>
<td>• Bid energy markets or ancillary services</td>
<td></td>
<td>• Access control</td>
</tr>
<tr>
<td>• Fast Load Shed</td>
<td>• Interface/optimize energy storage</td>
<td></td>
<td>• Security in lifecycle</td>
</tr>
<tr>
<td>• Island to Grid Resynch</td>
<td></td>
<td></td>
<td>• Information security governance</td>
</tr>
<tr>
<td>• Black Start Restoration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Power Quality Analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### High-Level Customer Requirements

### Advanced Microgrid Control Solution Benefits

### Specific Functional Requirements
MGMS: Grid Connected
Advanced Microgrid Controls Enables Integrated Grid

- Interconnected Grid to Integrated Grid
  - Better integrate renewables, storage and other DER
  - Grid recovery and healing
  - Optimization of system energy and load management

- Advanced Microgrid Controls enable:
  - Transparency and data accessibility
  - Prosumers
  - Distribution-level power markets
  - Grid stability
  - Safety and protection
Contact

Maggie Clout
Business Development Manager
Microgrid
Mobile: 404-426-3068
Email: maggie.clout@siemens.com