Smart Grid Division

Decentralized Energy Districts And Microgrids
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Infrastructure & Cities Sector
Siemens Industry, Inc.
Evolution of the Energy Grid

1900: Thomas Edison develops the first electric systems

1950: Rural Electrification and continued Industrialization

1980: Grids are required to power the sprawling growth of suburbanization

2020: “Re-urbanization” of cities is changing the way we work and live and has the potential to bring awareness, education, and responsibility to energy use
Why do energy grids need to change?

Increasing Energy Demand

By 2030, power consumption will grow to roughly 33,000 TWh - a 63 percent leap!

<table>
<thead>
<tr>
<th>Year</th>
<th>Fossil energy sources</th>
<th>Renewables</th>
<th>Nuclear</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>68%</td>
<td>32%</td>
<td>0%</td>
</tr>
<tr>
<td>2030</td>
<td>54%</td>
<td>46%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Security Concerns & Regulation

7 Million people without power during 2012 Hurricane Sandy and billions in damage

Renewable Energy Adoption

In 2011, renewable sources of energy accounted for about 9.3% of total U.S. energy consumption and 12.7% of electricity generation

Aging Infrastructure & Electrical Loss

Today, in the U.S. power grid: 70% of transformers and 60% of switchgear are over 25 years old

Source: US Energy Information Administration, Institute for Energy Research
Weather patterns are becoming more extreme, mostly due to climate change…. resilient grids!

- Climate change leads to higher temperatures, rising sea levels and more rainfall
- Increasing number of extreme weather events
- Increasing urbanization and settlement patterns lead to higher damages
- 2012: US$ 160 bn damage worldwide (67% in USA)

Figure 1: Number of recorded disasters
Source: EMDAT-CRED, Brussels
Why Resilience? USA, New York City 2012

- Hurricane Sandy was second costliest in US history
- More than 8 million people without power
- US$ 50 bn in damage
- NYSE down for two days – prior 2 day stretch was in 1888
- 2/3 of storm surge damage exceeded 500 year FEMA* demarcation

*Federal Emergency Management Administration: 2/3 of storm surge damage exceeded 500 year FEMA demarcation in New York City
Why Resilience?
Disasters hit developed & developing nations

- **Hurricane Sandy, 2012**: $50bn in damages, 2\textsuperscript{nd} costliest in US history
- **USA Droughts, 2011 & 2012**: $28bn in damages
- **Japan Tsunami, 2011**: $210bn damages, geopolitical consequences
- **UK Winter Snow Storms, 2010/2011**: Cost the UK economy $1.5bn per day, total $20bn
- **Haiti Earthquake, 2010**: 220,000 deaths, >300,000 injuries, 1.5m people homeless
- **Europe Heat Wave, 2003**: 66,720 deaths across Italy, France, Spain, Germany, Portugal
- **Northeast US**: Five “100 year” storms in three years
The State of the Utility Market

Key Challenges identified by sampling of 527 IOU/Muni/Coops

- Old Infrastructure: 48%
- Current Regulatory Model: 32%
- Aging Workforce: 31%
- Distributed Generation: 30%
- Flat Demand Growth: 28%
- Smart Grid Deployment: 23%
- Grid Reliability: 21%
- Coal Plant Retirements: 17%
- Renewable Portfolio Standards: 17%
- Energy Efficiency Mandates: 16%
- Emission Standards: 12%
- Cybersecurity: 11%

## Solutions Landscape: Elements

<table>
<thead>
<tr>
<th>Enterprise</th>
<th>Generation Planning</th>
<th>Common Modeling</th>
<th>Historical Information</th>
<th>Engineering &amp; Planning (T&amp;D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis</td>
<td>Energy Market Management (P)</td>
<td>Energy Market Mgmt (O)</td>
<td>Dist Network Applications</td>
<td>DER Optimization</td>
</tr>
<tr>
<td></td>
<td>Gen Optimization</td>
<td>Trans Network Analysis</td>
<td>Dist Training Simulator</td>
<td>DR Modeling</td>
</tr>
<tr>
<td>Control</td>
<td>Distributed Control System</td>
<td>SCADA, Auto Gen Control, Wide Area Monitoring</td>
<td>Distribution SCADA, Outage Mgmt Sys, Mobile Work Force Mgmt</td>
<td>DER/DR Management, MDMS</td>
</tr>
<tr>
<td>Apparatus &amp; Device</td>
<td>RTUs, Data Concentrators, GTs, CCP, ST, WP</td>
<td>Breakers, Xfrmr, Cap Banks, FACTS/SVCs, PMUs</td>
<td>Dist Auto, Cap Banks, Switches, Reclosers, Tiered Cont., Xfrmr</td>
<td>Auto Meter Reading, DSR (Customer), Home Area Networks</td>
</tr>
</tbody>
</table>

### Transverse Systems

- **Generation**
- **Transmission**
- **Distribution**
- **Consumer**
# Solutions Landscape: Elements

## Enterprise-wide Resource Optimization

- **Enterprise**
  - Generation Planning
  - Common Modeling
  - Historical Information
  - Engineering & Planning (T&D)

## Knowledge-based Decision Support

- **Analysis**
  - Energy Market Management (P)
  - Energy Market Mgmt (O)
  - Dist Network Applications
  - Dist Network Applications Mgmt
  - DER Optimization
  - DR Modeling
  - Load Modeling

## Real-time Integrated Operations

- **Control**
  - Distributed Control System
  - SCADA
  - Wide Area Monitoring
  - Distribution SCADA
  - Mobile Work Force Mgmt
  - DER/DR Management
  - MDMS

## Ubiquitous Cost-effective Communications

- **Communications**
  - In Plant (LAN)
  - Satellite
  - μWave
  - Cell
  - μWave
  - Telephone
  - Radio
  - PLC, WIFI, WIMAX
  - BPL
  - Manual

## Distributed Intelligent Apparatus/Devices

- **Apparatus & Device**
  - RTUs, Data Concentrators
  - Breakers
  - Cap Banks
  - Dist Auto
  - Reclosers
  - Auto Meter Reading
  - DSR (Customer)
  - Home Area Networks
  - GTs, CCP, ST, WP
  - Voit Regs
  - Cap Banks
  - SVG
  - PMUs
  - Switches
  - Tiered Cont.
  - Xfrmr

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*Diagram showing the connections and relationships between different elements of the Solutions Landscape.*

*Generation, Transmission, Distribution, Consumer labels on the diagram.*
Decentralization of grid design

From centralized, unidirectional grid …

… to distributed energy and bidirectional energy balancing
Integrated Resilient Grid Solutions

Integrated Distributed Resources

- Market Management & Analytics
  - MMS

- Energy Balancing & Demand Response
  - DRMS

Integrated Grid Resources

- Industrial
- Commercial
- Residential
- Wind
- Solar
- Batteries

Building, Home, Distributed Energy Management Systems

Balancing of Resource Capacity for Reliability and Economics

Grid Modernization

- Grid Planning & Asset Analytics
  - PSS™/E, PSS™/SINCAL, SGEM

- Control Center
  - EMS/DMS/OMS/WFMS

- Substation
  - Substation Automation

- Automated/Controllable Equipment
  - Recloser
  - Switch
  - Capacitor Bank
  - DER

Grid Reliability and Resilience

Bi-Directional Management of Customer Energy Information

Informed Consumption

- Customer Care & Consumer Analytics
  - CRMS

- Consumer Information Management
  - MDMS/AMI

- Intelligent Field Devices (i.e. Meters)

- Industrial
- Commercial
- Residential
Movement toward mixed decentralized design...

- Apply resilience planning as a guiding principle for future infrastructure investments ("Inside-out" distributed design)
- Resilience built on Reliability, Efficiency and Sustainability
- Develop a strategy for prioritizing necessary upgrades, investing in new generation assets and allowing the electrical delivery grid to fail in predictable layers of demand priority

### Energy District Structure

#### Level 1: Critical infrastructure - Resilient Microgrid

#### Level 2: Districts of partial sustainability

#### Level 3: Self-healing zones of reliability

#### Level 4: Utility Service Area

### Resilience Plan

- **Level 1** (Resilience): Most critical areas for self-sustaining power infrastructure
- **Level 2** (Sustainability): Level 2 Efficiency & Self-healing
- **Level 3** (General reliability): Least critical areas for self-sustaining power infrastructure

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## Decentralization of Grid Design and Operation

<table>
<thead>
<tr>
<th>Grid Capability</th>
<th>Supporting System Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resiliency</strong>, Utility <em>coordinated</em> decentralization of generation and delivery design - <em>Integrated</em> Network and Distributed Resource Management</td>
<td>Microgrids, multi-utility coordination (water, wastewater, transportation, etc.), critical infrastructure support, decentralized resource dispatch (f/v), Community Storage</td>
</tr>
<tr>
<td><strong>Sustainability</strong>, Consumer driven distributed generation - <em>Proactive</em> network and demand management</td>
<td>Demand Response, Renewable Integration, Adaptive Protection, Look-Ahead Forecasting, ADMS (load transfer, optimization), Storage</td>
</tr>
<tr>
<td><strong>Efficiency</strong>, <em>Active</em> Network Management - Automation Driven, Visibility, Supervisory Control</td>
<td>Self-healing, FCIs, CVR, Voltage Leveling, DMS (SCADA, FLISR) Storage, Crowd Sourcing</td>
</tr>
<tr>
<td><strong>Base Reliability</strong>, <em>Passive</em> or <em>Reactive</em> Network Management – Problem/Process Driven</td>
<td>OMS, MWFM, IVR, Protection, Transmission EMS</td>
</tr>
</tbody>
</table>
## Defining Layers of Delivery Infrastructure Criticality

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
</table>
| **Critical infrastructure - Resilient Microgrid** | - Renewable energy sources and other distributed generation enable complete independence from the grid under selected or extreme conditions. Area demand response is able to manage capacity and variation.  
- Infrastructure of Hospitals, Data Centers, Military Bases, Public Safety, etc. |
| **Districts of partial sustainability** | - Distributed renewable and traditional energy sources enable significant energy demand to be met while approaching grid independence. Eco-districts where off-set is green. Area demand response to manage capacity.  
- Airports, rail systems, marine ports, university campuses, etc. |
| **Efficiency & Self-healing zones of reliability** | - System designed with redundant feed paths and switchable connection points  
- Developed automation, monitoring, and control of feeder equipment  
- Enhancement of Control Center applications for DMS and efficiency |
| **Utility zones of general reliability** | - Utility reliability measures address outage duration and frequency averages  
- Maintenance and expansion is driven by the current rate structure  
- System design supports an “average” level of reliability for all customers |
City infrastructure with sustainable and resilient energy districts

- Lincoln Park Zoo
- Red Line (Elevated Train)
- Residential Area
- Water Tower & Water Intake
- Northwestern University Hospital
- Navy Pier – Tourist District
- Union Station (Train Transit)
- City Hall
- Soldier Field (da Bears)
- Midway Airport

Level 1

- Resilience

Level 2

- Sustainability

Level 3

- Efficiency & Self-healing

Level 4

- General Reliability

Demand Priority

Energy Required

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Microgrids…
• Are scaled down versions of the centralized power system that generate, distribute, and regulate the flow of electricity
• Operate grid connected or islanded and, if required, can switch between the two.
• Integrate decentralized power generation assets and controllable loads.

Note:
• Backup Power System are usually for emergency and generally cannot operate more than 1 day
• Cogeneration System are by-product of main industrial process, such as reusing heat to produce electricity or using the electricity produced for industrial process for other purpose,
• Microgrid requires distributed power generation; can be an evolution of existing asset (CHP) or new installation
• Distributed power generator system becomes a microgrid if a networked set of loads can use its electricity for a sustained period
• Microgrids are not necessarily “clean” power but most incentives require renewable power
What is a Microgrid?

**Design of an example Microgrid**

**Components (SW and HW)**

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

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

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

- **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.

DG=Distributed generation, C(C)HP=Combined (Cooling) Heat & Power
City Transformation

- **Micro-Grids, Eco-districts, Critical Infrastructure Zones**
- **Energy Reliability & Partial Sustainability**
- **Renewable Integration**
- **Active “real-time” Energy Management**
- **“Prosumer” Energy feedback to Utilities**
- **Collaboration with City Planning & Utilities**
- **Resilience for 24-hr service**
- **Integrated Demand Response & Variable Resources**
- **Integrated Water & Utility Network Management**
- **Cleaner Fuel Consumption**
- **Energy Education**
- **Energy Budgets**
- **Energy Efficiency Appliances**
- **Energy Adoption**
- **Energy Efficiency Investment**
- **Community Education**
- **Recycling Programs**
- **Awareness of Environmental Impact**
- **Net-Zero Consumption**
- **Government**
- **Landfills**
- **Residential Homes**
- **Commercial Buildings**
- **Infrastructure Investment**
- **Energy**
- **Water**
- **Traffic**
- **Air Quality**
- **Energy Adoption**
- **Financial Incentives**
- **Infrastructure Investment**
- **Service Goals**
- **City Goals**
- **Energy Efficiency**
- **Energy Reliability & Partial Sustainability**
- **Self-Healing Capability**
- **Renewable Integration**
- **Renewable Adoption**
- **Financial Incentives**
- **Energy Efficiency**
- **Energy Budgets**
- **Energy Education**
- **Goals & Standards**
- **Integrated Traffic System & Utility Network Management**
- **Advanced Consumer Relationship through Information**
- **Integrated Water & Utility Network Management**
- **Cap and Trade Carbon Market Participation**
- **Community Management of Emissions**
- **Government Landfills**
- **Traffic**
- **Air Quality**
- **Water/Wastewater Treatment**
- **Public Services: Hospitals, Airports, etc.**
Application Areas

- K-12
- Light Industrial
- Higher Ed
- Hospital
- Airport
- Stadium
CHP Definition:
A system for distributing heat generated in a centralized location for residential and commercial heating requirements such as space heating and water heating. The heat is often obtained from a cogeneration plant burning fossil fuels but increasingly biomass, although heat-only boiler stations, geothermal heating and central solar heating are also used, as well as nuclear power.

Examples of energy-districts:
- NYC steam system - largest commercial district heating system in the U.S.
- Denver's district steam system is the oldest continuously operated commercial district heating system in the world. It began service November 5, 1880
- Seattle steam company operates a district system in Seattle
Decentralized Resilient Energy-Districts
Revealed by Hurricane Sandy

Co-Op City, Bronx, NYC

- 14,000 apartments
- 35 high-rise buildings
- 40MW steam turbine generator, plus CHP
- Operates on a micro grid
- Retained power for 60,000 residents
Micro Grid
New York University Natural Gas CHP, USA

- Combined Heat and Power Plant ordinarily provides efficient energy for the university, but is also connected to the grid
- When Sandy knocked out the city’s power, the plant switched to micro-grid operation
- Larger buildings and core campus received continued supply through the storm and the following weeks
- Rest of neighborhood in darkness
- Additional benefits: 23% CO₂ reduction, utility savings of $5-8m per year.
Example Project: CHP at Naval Stations in Great Lakes, IL

<table>
<thead>
<tr>
<th>Location</th>
<th>Great Lakes, Illinois</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campus Size</td>
<td>278 buildings</td>
</tr>
<tr>
<td></td>
<td>10.9 million SF of occupied space</td>
</tr>
<tr>
<td>Installation Costs</td>
<td>$34,110,909(^1)</td>
</tr>
<tr>
<td>Annual Savings</td>
<td>$3.5 million(^1)</td>
</tr>
<tr>
<td>Began Operation</td>
<td>Summer 2005</td>
</tr>
<tr>
<td>Supplier</td>
<td>Ameresco</td>
</tr>
</tbody>
</table>

Background:
- Facilities were aging and Energy Policy Act (EPACT) mandated reduction in energy consumption in all federal facilities
- NSGL was confronted with expanded responsibilities and shrinking budgets
- Ameresco along with the Naval Facilities Engineering Command, developed a long term plan to upgrade and modernize the NSGL facilities utilizing third party financing.
- A three-step plan was developed and implemented to repair / refurbish / upgrade buildings, upgrade the distribution systems, and improve the existing central plant with CHP.
- The major challenges to implementing the plant upgrades via a CHP system included:
  - Upgrading the central plant without disrupting on-going operations
  - Operating the naval base independent of the utility grid
  - Complying with new federal regulations without adequate appropriations

\(^1\) Economics exclude 1993 installation of back pressure steam turbines.
The Smart Polygeneration Microgrid has been developed for University of Genova, in its campus in Savona. The system is a microgrid (with its own grid) connected to the national grid by a MV connection. Although the size (in terms of nominal power) is not huge, the system is complex and there are many generation, storage and load units to be managed.

### Power Generation:
- 2 cogen GTs
- 1 PV plant
- 3 cogen CSPs

### Loads
- 4 LV electric Boxes
- 3 Thermal Loads
- 3 Charging Units for Electric Vehicles

### Storage:
- 1 Electrochemical Energy storage unit
- 3 thermal storage units

### Thermal generation
- 2 Boilers
- 1 Electrical Chiller
- 1 Absorption Chiller
- Cogen heat from GTs and CSPs

DEMS is a SW tool which is able to optimize the management of electrical and thermal energy flows in a Smart Grid/ Micro grid.

**Planning Functionalities:**
- Weather, Generation and Load Forecast
- Economically optimized Unit Commitment

**Online Functionalities:**
- Monitoring of every unit and of the exchange with the grid
- Manual and automatic control of each controllable unit
- Possibility to interact with DSO
- Possibility to provide primary reserve service
Parker Ranch, Hawaii

- 250,000 Acres, including the city of Waimea (~7,000 residents)
- 175 Miles of water pipeline, with 4 reservoirs, 2 wastewater lift stations with 40hp motors
- Hospital, Commercial area, Industrial Park
- Potential and preference for renewable resources (solar, wind, tidal water, etc.)
- Desire for integration with local utility
- Focused on environmental and economic strategic goals

**Microgrid Implementation Stages**

1) Immediate Ranch Projects 3-5MW
2) Community Microgrid ~20MW
3) Strategic Concepts >50MW
KCP&L Demonstration – True End-to-End Smart Grid

End-to-end SmartGrid Built Around a SmartSubstation
British Columbia Institute of Technology

- 116 Remote communities in BC with first nations communities (20% of all remote communities in Canada)
- Reserves currently fed by Diesel or BC Hydro Grid
- Transport Cost and Access to first nations is very expensive

**Solution**

- Integration of 250 kW photovoltaic panels incl. inverters and Building Management System
- 500 kWh of Li-Ion energy storage to support a portion of the islanded load
- Mitigate the impacts of electric vehicle charging on the main grid through use of energy storage.
- Multiple distributed energy resources on the same distribution network including optimal dispatch and islanding.

Project Scope

- Consulting
- Design
- Gen. Assets
- System level
- Communication
- Supervision.
- MG Int.
- Const.
- O&M
Pantex, Military Microgrid

**PROJECT BENEFITS:**

Cost-effective Microgrid to provide Energy Security for the NNSA Pantex facility in Texas by integrating high availability, renewable Wind power.

11.5 MW total power generation from five reliable Siemens 2.3 MW Wind turbines.

Uptime ensured with real-time monitoring from Siemens warranty & maintenance team, supporting over 4.6 GW of wind power generation across the US.

Microgrid approach includes utility interconnect to enable excess power sale to local grid.

Developed and financed via Siemens Energy Savings Performance Contract (ESPC) with DoE. Low cost financing without leveraging US Federal tax incentives

Energy savings for NNSA Pantex 100% funds the project, including multi-year maintenance.

Siemens team includes TVIG, an award-winning Veteran-owned small business.
Thank you for your attention

Ken Geisler
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Infrastructure & Cities Sector
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Answers for infrastructure and cities.