Smart Grids

A Perspective on Market Readiness
Global Data Points
Workshop 12 March 2008
R. Masiello
What do SmartGrids mean for:

- **Governments**
  - A policy deliver mechanism for green energy
  - Actions to enhance supply security
  - Need to have assurance of the need case
  - Mechanisms to ensure efficient investment

- **Regulators**
  - Concrete actions: what and by when
  - What are the opportunities; what are the risks?

- **Companies**
  - Having choice, quality, and security
  - Enabling involvement and a positive statement

- **Customers**

A Common Vision but different Value Propositions
EU Technology Platform: SmartGrids

- SmartGrids: ensuring tomorrow’s electricity networks will be fit for purpose, across Europe
- The Technology Platform brings together key stakeholders
- Vision document & Strategic Research Agenda published
- The current task is the Strategic Deployment Document
- Framework-7 funding: €2.3bn over 7 years for energy research) and includes SmartGrids

Download the new SmartGrids video!

www.smartgrids.eu
beyond EU – some Utility SmartGrid actions

Utility of the Future - Duke Energy

gridSMART – American Electric Power

Intelligrid – CEMIG (Brazil)

Blueprint for the Future – Pepco Holdings, Inc.

Circuit of the Future – Southern California Edison, Kansas City Power & Light Co.

Intelligent Utility Grid - CenterPoint Energy

Power the Future – WE Energies

• How can initial investments in AMI or Smart Metering be leveraged into a broader Smart Grid architecture?
• Which technologies are ready for investment now? Which ones should be deferred?
• What is the right regulatory recovery scheme (short and long-term)?
• How will consumers accept and interact with these applications?
• How will incremental CapEx requirements be integrated into existing grid resource plans?
• What rate and service offerings are needed to maximize consumer participation?
• How well will standards drive innovation, while maintaining security and reliability?

There are several other programs not listed, including Oncor, Progress Energy, FPL and others
Coming to a network near you?

Projections for Global Renewable Energy 2010 & 2020

Note: Projections of modern renewables (including small hydro, excluding large) based on 11.5 percent growth per year, over the period 2001-2005.

Sources: UNDP, UNDESA, and WEC, 2000 and 2004; REN21, 2006; And IEA, 2006
The Key Drivers

> Supply Security > Reasonable Cost > Sustainability >

- Sustainability: less carbon and less waste, greater efficiency
- Impact of neighbours: security of sources, loop flows, incidents
- Less dependence on traditional ‘economy of scale’
- Mini, micro and community-scale advantages now identified

- Significant New Residential Construction Offering PV as Option
- Consumer side Energy Storage a Logical Adjunct to PV
- Leads to Grid Interconnection Issues and Higher “Potential Peak” Loading Conditions
- Grid Reliability (SAIDI) Will Have to Approach 6 Sigma to Maintain Consumer “Relevance”
EU targets 2020: 3x20

- 20% reduction CO₂ emission
- 20% renewable sources
- 20% energy saving
The Key Stakeholders
‘those with a shared interest in success’

• T&D network companies
• Their shareholders
• End customers
• Governments
• Regulators
• Manufacturers
• Academia
• Research institutions
• Consultants & Specialists

Also:
• Finance providers
• Insurers
• Company staff
• ‘the public’
• others….?

New Entrants
• Retailers (Home depot)
• Local Heating/Plumbing
• Home Builders
The Valley of Death

Although risk is reducing, costs climb at the demonstration stage:
• Who funds this stage – it is no longer ‘R&D’
• EU State Aid rules constrain public funding
• For energy, an ‘undifferentiated product’, there is no premium price, and rarely a niche market
Case Study: The UK Situation

Ofgem, the regulator, identified in 2004 that:
• investment levels would be beyond recent experience
• there are diverse new challenges for networks
• the issues are Europe-wide and international
• Innovation was not encouraged by the RPI-X framework

Why is a Regulator interested in innovation?
– Ofgem’s primary duty is to customers, both today and in the future
– it seeks to promote effective and efficient investment, and
– recognises that engineering innovation has a role where it adds value
UK Distribution Company R&D

Trend since 1990
UK Distribution Company R&D trend

Impact of new incentives

Privatisation

- c.180 projects
- Projects are initiated by the companies
- Ofgem does not ‘approve’ each project
- Only one company is spending to its cap
- Av. intensity is 0.27%
- Forecast benefit total €70m (NPV)

* Data from 1989/1990 to 2003/2004 is the collaborative spending on R&D amongst the DNOs through a single provider.
GB Distributed Generation Connection Costs
beware the sting in the tail!

NOTE
1. Some 50% of projects DG can be connected at nil reinforcement cost
2. There is 40% that connected at less than £100/kW
3. But there is 10% that could cost up to £10,000/kW
4. High cost elements grow as spare capacity used up beyond 2010.

Beware the “high cost”
Graph is ranked by order of cost, not timing of projects. 2004 data. Projects total 4,000MW of DG

Innovation by the network companies seen to be essential to counter this cost escalation
The Scale of the Challenges

UK Wind capacity Required by 2020  BWEA Jan 08

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[Bar chart showing the comparison of onshore and offshore wind energy capacity required by 2020, categorized into 'Required by 2020', 'In planning', 'Approved', 'Under construction', and 'Operational'.]
# Smart Grids: practical application

## Small Users

<table>
<thead>
<tr>
<th>Demand</th>
<th>Metering</th>
<th>Gen.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsive demand control of white goods, aircon, heating.</td>
<td>ROCOF etc AC interfaces</td>
<td>Condition monitoring real time</td>
</tr>
<tr>
<td>Smart Meters, basic functionality</td>
<td>Converter DC interfaces</td>
<td>Fault prediction</td>
</tr>
<tr>
<td>Smart Meters, advanced functionality</td>
<td>Micro-generators with export capability</td>
<td>New network voltage control for DER feeders</td>
</tr>
</tbody>
</table>

## Distribution

<table>
<thead>
<tr>
<th>Gen.</th>
<th>Network Assets</th>
<th>Network Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community level micro-generation management</td>
<td>Flow control devices</td>
<td>Quality of supply enhancement</td>
</tr>
<tr>
<td></td>
<td>Active distribution networks</td>
<td>Waveform enhancement</td>
</tr>
<tr>
<td></td>
<td>Distribution power electronics</td>
<td>Storage for peak smoothing and investment deferral</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DSM to EMS</td>
</tr>
</tbody>
</table>

## Transmission

<table>
<thead>
<tr>
<th>Gen.</th>
<th>Network Assets</th>
<th>Network Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fault Level Limiters</td>
<td>Condition monitoring real time</td>
<td>Dynamic plant ratings</td>
</tr>
<tr>
<td>Off-shore connections</td>
<td>Flow control devices</td>
<td></td>
</tr>
<tr>
<td>Off-shore substations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment decision tools</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon-costed asset management</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Large Users

<table>
<thead>
<tr>
<th>Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Off-shore substations</td>
</tr>
<tr>
<td>Grid-friendly intermittent gen controls</td>
</tr>
<tr>
<td>MW scale battery devices</td>
</tr>
</tbody>
</table>

## Energy Efficiency Innovations

- Interactive customers
- Smart Meters, advanced functionality
- Community level micro-generation management
- Flow control devices
- Fault Level Limiters
- Active distribution networks
- Distribution power electronics
- Quality of supply enhancement
- Waveform enhancement
- Storage for peak smoothing and investment deferral
- DSM to EMS

## Virtual Power Plant

- Distributed ICT and Settlement systems
- Smart Meters, full gateway
- VPP Virtual Power Plant for mini and micro generation
- Fully Active D networks
- Modelling tools
- Stability control
- Self-healing grids
- Islanded operation capability
- G to T through flows
- Off-shore grids and interconnection
- Integration of H2 transmission
- Self-healing grids
- Balancing Services from aggregated DER
- Pan-EU interoperability
- Integration of Commercial Energy Management Systems
- GW scale marine storage

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**Level 1** Technology is Available Now  **Level 2** Technology is Near to Market  **Level 3** Research & Development is needed
U.S. MID-RANGE ABATEMENT CURVE – 2030

Cost
Real 2005 dollars per ton CO₂e

T&D Technologies

POTENTIAL IMPACT ON OUR BUSINESS

TIMEFRAME FOR TECHNOLOGY READINESS

NOTE: This chart only reflects timing around technical readiness and does not reflect timing around overcoming economic hurdles.
Example Of A Strategic Technology: Sensors

Description

Links to Utility of the Future concept

The hardware component of Distributed Intelligence (the two other components are Communication & Software)

Application

Power conductor sag sensors can determine sag, tension and line capacity

Transformer coil temperature sensors can determine transformer capacity and predict failure

Underground cable sensors can detect hazardous situations to support preventative maintenance

Other low cost physical sensors can be used to measure voltage, current and phase angle in power systems; pump & motor vibration in generating stations; vehicle/personnel detection for security, etc.

Current Status

Dust Networks has deployed “motes”, miniature sensors/radios, for Department of Defense as well as industrial applications.

It is possible that nano-sensors could be adapted for this application and deployed within 5-10yrs.

WHAT WOULD YOU MEASURE IF IT WAS FREE TO DO SO?
HOW CAN THAT INFORMATION BE TURNED INTO VALUE?
Example Of A Disruptive Technology: Storage

Description
Superconducting Magnetic Energy Storage
SuperVAR
Nano-structured electrodes for batteries

Application
- Dynamically injecting/absorbing reactive power
- Premium-quality power products for customers
- Defer more capital-intensive infrastructure investment
- Enhance system efficiency
- Act as spinning reserve
- Reduce grid congestion.

Current Status
Energy storage provides only about 2.5% of total electricity capacity in the US – nearly all of it from pumped-hydro installations used for load shifting (150 facilities in 19 states totaling 22GW).
Driving down cost is still major the challenge and focus of current research efforts.
Nano-technology developments could significantly enhance energy storage capacity & battery life for EVs and portable electronics.
## Technologies For Addressing System Losses

<table>
<thead>
<tr>
<th>Technology</th>
<th>Application</th>
<th>Current Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composite conductors:</td>
<td>Operates at higher temps without significant line sag and with lower losses.</td>
<td>Aluminum composite-core conductors, terminations, and suspensions have been developed by 3M and demonstrated in field by some US and European utilities.</td>
</tr>
<tr>
<td>- High strength composite-core replaces steel in existing steel-reinforced or supported aluminum conductors to enable longer, stronger lines with higher capacity</td>
<td>Transports 2 to 3 times as much power over the same ROW without tower modifications.</td>
<td>The main barriers for deployment of fiber reinforced overhead conductors are higher cost per foot than conventional cable and the development of new methods of splicing and handling.</td>
</tr>
<tr>
<td>— Fiber reinforced overhead conductors:</td>
<td>Conductors core will be less than 25% the weight, have higher tensile strength, and have half the thermal expansion</td>
<td>Current improvements are conservatively estimated to be 150-300%</td>
</tr>
<tr>
<td>— Aluminosilicate fibers — lighter and less luminous than other composites, can be used to reinforce overhead conductors</td>
<td>Avoided cost of additional lines, support structures and rights of way.</td>
<td>Avoided cost of additional lines, support structures and rights of way.</td>
</tr>
<tr>
<td>High Temperature Superconducting (HTS) cable:</td>
<td>Enables more compact cable installations with 3 to 5 times more capacity than conventional circuits at the same or lower voltage.</td>
<td>Over the past decade, several HTS cable designs have been developed and demonstrated.</td>
</tr>
<tr>
<td>— Carries much greater power density than conventional copper-based cables and are capable of serving very large power requirements at medium voltage ratings.</td>
<td>Exhibits much lower resistive losses than occurs with conventional copper or aluminum conductors.</td>
<td>ASC/TVA rolling out first commercial product – said to deliver 150 times the electricity of conventional wire, but is also 2 to 3 times as expensive as copper.</td>
</tr>
<tr>
<td>FACTS (Flexible AC Transmission Systems) devices:</td>
<td>Controls the magnitude and direction of real and reactive power flows</td>
<td>Established technology, but industry has been slow to adopt because of high installation prices.</td>
</tr>
<tr>
<td>— Power electronic devices that can help to prove control and stability of the transmission grid by providing reactive power supply.</td>
<td>Provides dynamic voltage support</td>
<td>Also, FACTS devices generally require the support of Wide Area Measurement Systems (WAMS) which currently only exist in prototype.</td>
</tr>
<tr>
<td></td>
<td>Reacts almost instantaneously to disturbances</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increases transmission capacity (potentially up to 50%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Improves overall system reliability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Allows for DER to be connected to existing grid without transmission expansion</td>
<td></td>
</tr>
</tbody>
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## Technologies For Addressing System Losses

<table>
<thead>
<tr>
<th>Technology</th>
<th>Application</th>
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</thead>
</table>
| Intelligent Universal Transformers: State of the art power electronic system will replace the single-function capability of conventional transformers with intelligent, controllable system that des multiple functions. | *Remote communication capability.  
Enhance power quality through sag correction and harmonic filtering  
Regulate voltage and power factor, thus reducing losses and increasing throughput  
Flexibility to deliver three phase power from a single phase line  
Improved Asset Management  
Contains no hazardous liquid dielectrics,  
Would not have to bypass for BPL  
Could facilitate metering at the transformer | EPRI is currently undertaking field prototype demonstrations for IUTs. |
| Amorphous Metal Core Transformers: A silicon steel core inside a transformer is replaced with amorphous metal which is easily magnetized and demagnetized in results in less than one-third the losses. | 60 to 70% lower core losses than other transformers in-service and new high efficiency silicon steel core transformers.  
low operating temperatures;  
size and weight comparable to silicon steel transformers | Amorphous metal and amorphous core transformers are now available  
Originally developed in the 90’s – but adoption slow due to high unit costs  
Are now more competitive due to rising costs of silicon steel. |
| Superconducting transformers: Copper-based windings in a conventional transformer are replaced by wire coils which incur substantially less resistance loss, bringing the efficiency rate transformer closer to its theoretical potential (100%). | 30% reduction in total losses  
45% lighter weight  
About 20% reduction in total cost  
Eliminate need for oil cooling, reducing associated fire and environmental hazards.  
Twice the overload rating capability for extended periods without insulation damage or loss of lifetime  
Unprecedented fault current limiting functionality  
Reduced operating impedance improves network voltage regulation. | An alpha prototype 5/10 MVA HTS transformer has been built by Waukesha Electric. This prototype demonstrated the technical and economic feasibility of 30/60 MVA and larger HTS transformers.  
Initial HTS transformers are expected to cost 30% higher with ownership costs 10% higher than conventional units. |
## Key Challenges Drive Need for Distributed Resources and Micro Grids

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Key Drivers</th>
<th>Potential Solutions</th>
</tr>
</thead>
</table>
| Increasing cost of new generation / transmission  
  – Cliffside estimates have increased from $2B-$3B | • Tight commodity markets  
  • Lack of skilled labor | • Build larger scale plants  
  • Increase smaller distributed generation  
  • Energy Efficiency – through better utilization |
| Green House Gas Initiatives | • Global Warming Concerns | • Increase renewable generation  
  • Increase environmental controls  
  • Increase Energy Efficiency |
| Increased reliability needs | • Increased congestion due to lack of investment  
  • Higher reliance on technology is changing customer needs for reliability | • Back up generation  
  • Dual Feed to Site  
  • Buried Infrastructure |
| Load Growth that is more variable – peaked | • Industrial flight  
  • Demographic Shift  
  • Energy intensity of economy is decreasing | • Increase peaking capacity both large and small scale |

As utilities continue to build out Smart Grids, they will further enable Micro Grids
Current Micro Grid Landscape

State Incentives for Distributed Resources / Micro Grid

<table>
<thead>
<tr>
<th>State</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA</td>
<td>$500 Million in incentives for distributed resources</td>
</tr>
<tr>
<td>Ohio</td>
<td>~$1 Million in grants to 26 distributed generation projects</td>
</tr>
<tr>
<td>Indiana</td>
<td>Distributed Generation Grant Program (DGGP) offers grants of up to $30,000 or up to 30% of eligible costs</td>
</tr>
<tr>
<td>North Carolina</td>
<td>Subsidized Loans with an interest rate of 1 – 3 percent</td>
</tr>
</tbody>
</table>

Source: Energy Velocity

Website with Incentives by State: http://www.eea-inc.com/rrdb/DGRegProject/Incentives.html
Micro Grids Can Be Used to Shape the Peak and Increase Utilization

- Increasing Residential Load is resulting in higher peak load
- Distributed generation may offer an opportunity for 'peak shaving' at the substation or feeder location

California Study: Impact on Load Shape of different Energy Initiatives

Source: GTI Distributed and Sustained Energy Center
Micro Grids will enable distributed Renewable Generation as Technology Matures

- Potential to reduce CO₂ emissions which are valuable in a Carbon constrained economy
- Contribute to meeting RPS

<table>
<thead>
<tr>
<th>Technology</th>
<th>Total Installed Cost (2006$’s) *</th>
<th>LCOE ($/MWh)** Developer Financed, w/o &amp; with PTC</th>
<th>Generation Capacity (GW) 06 Add 2015</th>
<th>NI ($MM)</th>
<th>ROE</th>
<th>Market Maturity</th>
<th>Pros and Cons</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Water</td>
<td>1500 to 1000</td>
<td>90/50</td>
<td>9 20</td>
<td>$50+</td>
<td>&gt;12%</td>
<td>Mid</td>
<td>Scalable, TechMat. Resource Avail.</td>
<td>Large scale, significant upside for technological advance, competitive with PTC</td>
</tr>
<tr>
<td>O-shore</td>
<td>2300 to 1800</td>
<td>100/60</td>
<td>29</td>
<td></td>
<td></td>
<td>Low</td>
<td></td>
<td>Low scale, fragmented and remains uneconomic</td>
</tr>
<tr>
<td>Photovoltaic</td>
<td>9500 to 4500</td>
<td>700/200</td>
<td>1.5 5.5 7</td>
<td>TBD</td>
<td>TBD</td>
<td>Mid</td>
<td></td>
<td>Low scale, fragmented and remains uneconomic</td>
</tr>
<tr>
<td>O-mass</td>
<td>2000 to 1900</td>
<td>85/75</td>
<td>1.5 5.5 7</td>
<td>TBD</td>
<td>TBD</td>
<td>Mid to High</td>
<td></td>
<td>Small Scale, very distributed, not competitive</td>
</tr>
<tr>
<td>O-mass</td>
<td>2400 to 1600</td>
<td>90/80</td>
<td>10 15.5</td>
<td>$10+</td>
<td>&gt;10%</td>
<td>Mid to High</td>
<td></td>
<td></td>
</tr>
<tr>
<td>O-mass</td>
<td>2400 to 1800</td>
<td>50/40</td>
<td>3 0.8 3.8</td>
<td>$10+</td>
<td>&gt;10%</td>
<td>Low to Mid</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table Notes:**
- LCOE: Levelized Cost of Energy
- NI: Net Income
- ROE: Rate of Return on Equity
- Generation Capacity (GW): Generation Capacity in Gigawatts
- Add 2015: Additions forecast for 2015
- Total Installed Cost: Total installed cost in $M (2006$’s)
- Developer Financed: Cost of energy with developer financed
- w/o & with PTC: Cost of energy without and with production tax credit
- Medium: Medium technology maturity
- High: High technology maturity
- Low: Low technology maturity
- $50+: Cost above $50 per MWh
- $10+: Cost above $10 per MWh
- $10+: Cost above $10 per MWh
- 06: Year 2006
Micro Grids will be valuable to Customers with Reliability Needs

<table>
<thead>
<tr>
<th>Description</th>
<th>Load (kw)</th>
<th>Cost Savings</th>
<th>Power Availability</th>
<th>Renewable Generation</th>
<th>Power Quality</th>
<th>Stand By</th>
<th>Peaking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food - Convenience Stores; Fast Food; Restaurants.</td>
<td>40-50</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>D</td>
<td>FC</td>
</tr>
<tr>
<td>Box Stores</td>
<td>200-400</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>FC/IC</td>
<td></td>
</tr>
<tr>
<td>Supermarkets</td>
<td>150-2,000</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>D/IC</td>
<td>FC/IC</td>
</tr>
<tr>
<td>Hospitals</td>
<td>100-6,000</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>IC/D</td>
<td>MT/IC</td>
</tr>
<tr>
<td>Hotels</td>
<td>200-2,500</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>IC/D</td>
<td>MT/IC</td>
</tr>
<tr>
<td>Large Office Buildings</td>
<td>400-3,000</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>IC/D</td>
<td>MT/IC</td>
</tr>
<tr>
<td>Universities</td>
<td>1,000-4,000</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>GT/D</td>
<td></td>
</tr>
<tr>
<td>Factories</td>
<td>500 and up</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>GT/D</td>
<td></td>
</tr>
</tbody>
</table>

Key: D Diesel; FC Fuel Cell; IC Internal Combustion Engine; MT Micro Turbine; GT Gas Turbine
Micro Grid Enables Delaying Distribution Investments

Deferment Benefit

- Defer 2 Years
- Defer 6 Years
- Defer 10 Years

Dollars ($ Million)

- Transformer at Substation
- 69 KV line
- New Circuit
- Install new Bank

5 MW at Substation ($2.4M)
Peak Power Management

Some Utilities are using Micro Grid to relieve peak loading - Today