Disrupting Our Way to a Sustainable Energy Future

May 5, 2015
Council for Chemical Research
Alexandria, Virginia
Today’s energy system is largely one way
Generation has evolved

Base

Intermittent

Storage
With technology advances, U.S. is now the world’s leading oil producer

Top World Oil Producers (2013)

1 United States
2 Saudi Arabia
3 Russia
4 China
5 Canada
6 United Arab Emirates
7 Iran
8 Iraq
9 Mexico
10 Kuwait
Horizontal drilling: the key disruptive technology behind this change

$100/barrel

$60/barrel
Thin-film solar voltaics have disrupted solar energy

**Solar farms**
Conversion rate before 2008: 10%
Now: 22-24%

**Solar shingles**
Not widely used before 2008
Conversion rate now: 19-20%

Image: Dow
Finding energy in surprising places

Image: Lucid Energy
New battery technologies provide grid-scale storage

Image: UniEnergy Technologies, Inc.
The amount of energy wasted by the US economy in 2012...

could power the United Kingdom for 7 years.
Lighting technologies are dramatically increasing efficiency

Efficiency: 10%

Efficiency: up to 50%
What do all these disruptors have in common?

Challenging conventional business models

Creating “prosumers” via decentralization
Future energy system will be two-way
Characteristics of the future energy system

Growing Asset Stress

Increased Variable Generation

More Dynamic Market

New Controllable Assets

Massive Data
How will we manage this disrupted energy system?
Modernize the Grid
Future power grid must meet new expectations and technical challenges

**Historical Expectations**
- Affordable Power
- Reliable Power
- Secure Power

**Emerging Expectations**
- Integrate renewable generation
- Increase grid-scale storage
- Electrify transportation
- Dynamic and responsive loads
IT meets ET: Key to realizing full potential of the future power grid

Data
Situational awareness

Simulation
Operations and planning

Tools
Real-time decision support
Deployment of a vast new sensor network is generating unprecedented real-time data

North American SyncroPhasor Initiative

- Power companies, utilities, vendors, DOE/labs, and universities
- High-resolution, time-stamped data
Rich new data streams are transforming grid management

<table>
<thead>
<tr>
<th></th>
<th>Today – SCADA data</th>
<th>Tomorrow – Phasor data</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety</td>
<td>voltage + current</td>
<td>+ phase angle</td>
<td>more information</td>
</tr>
<tr>
<td>Velocity</td>
<td>1 sample / 4 seconds</td>
<td>30-120 samples / second</td>
<td>~200x faster</td>
</tr>
<tr>
<td>Volume</td>
<td>8 terabytes / year</td>
<td>1.5 petabytes / year</td>
<td>~200x more data*</td>
</tr>
<tr>
<td>Veracity</td>
<td>unseen ms-oscillations</td>
<td>oscillations seen at 10ms</td>
<td>greater accuracy</td>
</tr>
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Real-time data ingestion from a distributed sensor network with myriad devices

- Cyber-secure sensor network
- Data provenance and privacy
- Real-time ingestion & curation
- Actionable analysis
Model complexity and time constraints drive use of high-performance computing

- State estimation
- Dynamic simulation
- Contingency analyses
- Stochastic optimization
Integrated model of transmission and distribution system requires 1B nodes

<table>
<thead>
<tr>
<th>Element</th>
<th>Nodes in Western U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>~10^2</td>
</tr>
<tr>
<td>Transmission</td>
<td>~10^3</td>
</tr>
<tr>
<td>Substations</td>
<td>~10^4</td>
</tr>
<tr>
<td>Distribution Feeders</td>
<td>~10^5</td>
</tr>
<tr>
<td>Customer Meters</td>
<td>~10^7</td>
</tr>
<tr>
<td>Appliances/Equipment</td>
<td>~10^9</td>
</tr>
</tbody>
</table>
Faster simulations will improve operations and planning

**Goal:**
- 10x > RT
- 1-2x > RT

**Current:**
- 2-15x < RT
- 5-30x < RT

**Simonation**
- Dynamic Simulation
- State Estimation
- Market Simulation
- Planning Analyses

**How fast the system needs**

**Operations and Planning**

**How fast the human needs**

- Minutes
- Days
- Hours
- Months
Tools
GridLAB-D provides a unified model of the key elements of the smart grid.

**Power Systems**

**Loads**

**Markets**

GridLAB-D models:
- Power flow
- End-use load behavior in thousands of homes
- Double-auction markets
Information visualization and decision support tools enable situational awareness

Small Signal Analysis Tool

Wide Area Hybrid Grid Health Tool
What’s Next?
Opportunities in the chemical enterprise

Renewables

Hydrogen

Storage

Catalysis

Materials

Electrochemistry
We invite you to collaborate with us