The Emerging Grid

- Natural Gas Generators
- Nuclear Power Plants
- Hydro power plants
- Wind Farms
- Solar Farms
- Transmission System
- Distributed storage
- Distributed wind
- Rooftop Solar
- Home Energy Storage
- Energy Efficiency
- Commercial Customers

Smart Grid functionality restores the balance

Hydro power plants
- Solar Farms
- Wind Farms
- Distributed storage
- Distributed wind
- Rooftop Solar
- Home Energy Storage
- Energy Efficiency
- Commercial Customers
Unprecedented Evolution

<table>
<thead>
<tr>
<th>Domain</th>
<th>Change</th>
<th>Future System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>• Reliability++, Economy++, Sustainability</td>
<td>Sustainable</td>
</tr>
<tr>
<td>Sources</td>
<td>• Fossil fuel to renewable</td>
<td>Renewable Distributed, Two way Stochastic</td>
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<tr>
<td></td>
<td>• Bulk centralized to distributed</td>
<td></td>
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<tr>
<td></td>
<td>• Highly Variable</td>
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<tr>
<td>ICCT</td>
<td>• Can control entire system through SW</td>
<td>Cyber-Controlled</td>
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<td></td>
<td>• Interdependency of physical and cyber</td>
<td>Cyber-Physical Secure, Private</td>
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<td></td>
<td>• Privacy and cyber-security issues</td>
<td></td>
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<tr>
<td>Actors</td>
<td>• Consumers can also produce and store</td>
<td>Prosumers Smart</td>
</tr>
<tr>
<td></td>
<td>• Consumers seek their own objectives</td>
<td>Massive</td>
</tr>
<tr>
<td></td>
<td>• Massive number of actors and devices</td>
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</tbody>
</table>

- Much more difficult to model and simulate grid complexity
- Challenges in Control, Management, and Industry Architecture
ARPA-E Prosumer-Based Distributed Control Project

• ARPA-E Green Energy Network Integration (GENI)
• Jan. 2012 – Dec 2014
• $2.7 Million
• Collaboration:
  – Santiago Grijalva (power systems),
  – Magnus Egerstedt (networked control),
  – Shabbir Ahmed (stochastic optimization),
  – Marilyn Wolf (cyber-physical systems)
  – About 15 graduate students.
• Project Objective: Demonstrate a massively scalable decentralized control architecture that can support the requirements of Future Intelligent, Sustainable Electricity Grids.
Project Summary

• Project Elements
  – Reference Architecture
  – Theory: Decentralized Agent-Based Control and Decomposition-based Optimization
  – Technologies:
    • Power-Communications Co-Simulator
    • Electricity Operating System,
    • Distributed Controllers
  – Large-Scale Simulation [TRL6]
  • IAB including MISO, PJM, NRECA, FERC, Brattle Group.
  • Vision inputs from about 100 stakeholders.
  • About 30 papers produced.
Concept 1: Prosumers

- A generic model that captures basic functions (produce, consume, store) can be applied to power sub-systems at any scale.
- The fundamental task is power balancing:
  \[ P_{INT} = P_G - P_D - P_{Loss} - P_{STO+} + P_{STO-} \]
- Energy services can be virtualized.
Concept 2: Decentralized Electricity Industry

- Interconnection
- ISO
- Utility
- \(\mu\)Grid, Building, Home

- Interactions occur among entities of the same type (prosumers)
- Can achieve massive decentralization
Concept 3: Prosumer Services

- Prosumer handles internal optimization and external coordination.
- Exposes standardized services
  - Energy balancing
  - Frequency regulation
  - Reserve
  - Sensing and Information
  - Forecasting
  - Security
  - Self-identification
  - Voltage control
  - Black Start
  - Etc.
Decentralized Control

- Self-Optimizing Regions in a Large-Scale RTO System.
- Tie-Line Bus LMP convergence using Decentralized Optimization.
Benefits of Decentralized Architecture

1. Scalable to infinite number of control points.
2. Reduces need for massive communication infrastructure.
3. Leverages sensing investment: smart meter, PMU, IED.
4. Enables otherwise intractable optimization problems
5. Supports integration of DERs
6. Eliminates single point of failure
7. Supports all forms of distributed intelligence
8. Empowers customers
9. Increases information privacy
10. Enhances cyber-security
11. Incrementally deployable
12. Backward compatible

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Technologies TRL [5-6]

- Decentralized Energy Scheduler
  - Much faster than state-of-the-art for large-scale ISO model.
  - Scales down to distribution/μgrid/home.
- Decentralized Frequency Regulation
  - Stabilization of large-scale ISO.
  - Scales down to distribution/μgrid/home
- Grid Operating System
  - Mathematically-proven protocols
  - Application framework
  - Distributed Control Library
- Co-Simulator
  - Power and communications
March 2014, Team wins DOE ACC Business Model Competition

• Regional DOE Competition focused on innovative business models for clean energy.
• Team proposed business models of a distributed control-based energy internet.
• Received first prize at $100k.
July 2014: Incorporation of ProsumerGrid, Inc.

- Decided to form start up company.
- ProsumerGrid, Inc. to further develop and commercialize ARPA-E project software that allows the effectively coordination and operation of emerging interacting energy systems.
  - Computational Simulation Software
  - Decentralized Real-time Control Systems
September, 2014 NSF I-CORPs Program

- To validate hypotheses, refine business model, and establish product market fit.
- I-CORPs Team

Santiago Grijalva (Principal Investigator)
- Associate Director for Electricity/Professor, Georgia Tech
- Former Director of Power Systems Center at NREL

Marcelo Sandoval (Entrepreneurial lead)
- Georgia Tech EE PhD Candidate, MBA
- Certificates: Intl. Business, Entrepreneurship, Lean Six Sigma

John Highley (Mentor)
- Owner of Energy and Environmental Enterprises
- Retired Managing Partner for Deloitte’s Global Energy & Utilities
I-CORPs Interviews

ISOs: regional

Electric Utilities System Operators: Cities

Facilities Energy Managers: Buildings

Residential Home Owners
I-CORPs Highlights

- Utilities vary in their level of sensing and automation, and have different regulations and renewable targets.
- Operational complexity growing fast.
- Needs vary, but there is a common theme around DER integration.
- Wanted: a software system capable of coordinating large-numbers of distributed energy subsystems.
  - Multi-layer, multi-scale simulation/analysis
  - Decentralized real-time control engines.
I-CORPs Decision: **GO!**

- Tested the problem
- Identified customer problems and needs
- Tested our value propositions
- Found Product Market Fit!
- Found Partners for Pilot Project

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Thanks!

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• For information on ProsumerGrid, Inc. contact Marcelo Sandoval: msandoval@prosumergrid.com