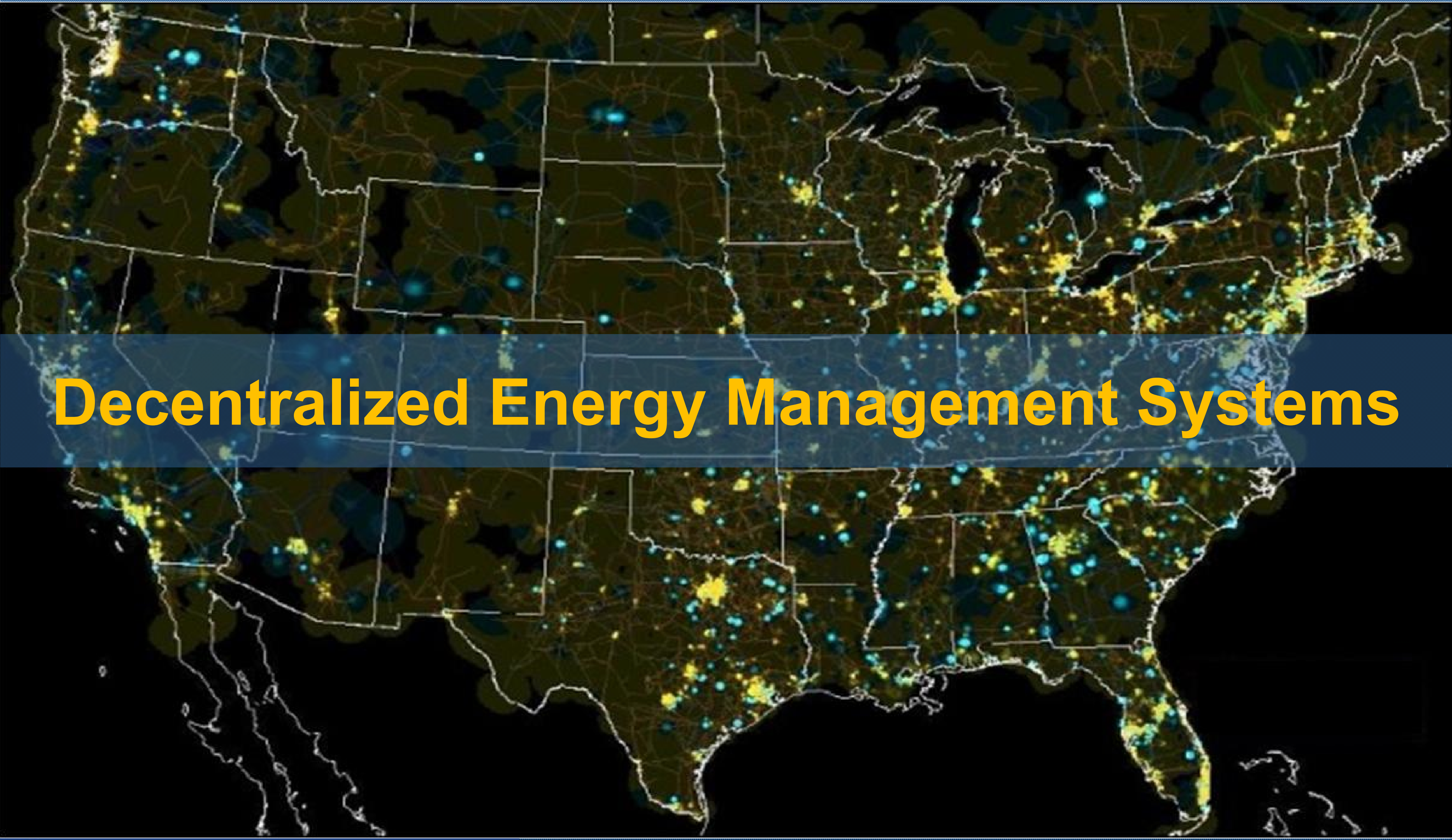
Presentation: May 2016



Decentralized Energy Management Systems

ProsumerGrid

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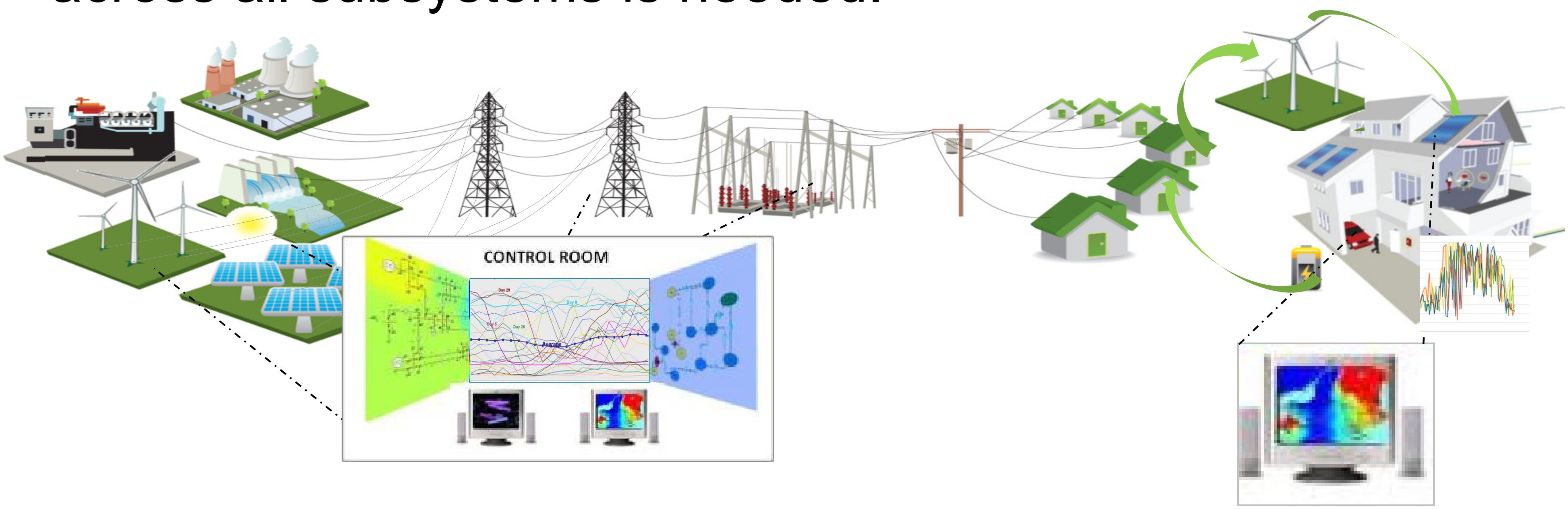
Chairman, ProsumerGrid, Inc.

Industry Trends

- Large amounts of distributed energy resources (DER) and smart devices are being integrated into the grid.
  - Space-time variability of DERs means that what happens in a region affects other regions and vice-versa.
- The future grid will have a billion smart devices and millions of decision makers. Thus much faster, better ***coordination*** across all subsystems is needed.



Two Grand Challenges

1. How can we ***simulate*** the operation of electricity grids with a massive number active and dynamic (DER-based) subsystems?
   - Must depart from simple power flow, into temporal optimization.
   - Problems easily become intractable. A distributed computation framework is needed.

2. How can we ***coordinate*** the real-time control and management of a billion devices and millions of subsystems to achieve the objectives of the grid?
   - Because it is impossible for a single organization to make all the operational decisions, coordination needs to be **decentralized**.

Decentralized

- Recognizes more than one decision-maker.

- Microgrids
- Demand Response
- Building Energy Management Systems
- Home Energy Management Systems
- Building, Home, Vehicle, X to Grid
- Transmission/distribution effects
- Consumer Empowerment
- Prosumers
- Imbalance Markets
- Distribution System Operators (DSO)
- ISO Seams Issues
- Wide-Area Control
- Etc. . . .

Use cases of decentralized coordination

ProsumerGrid Origins

- Georgia Tech ARPA-E GENI Project on Distributed Control
  - (Jan 2012-May 2015)
  - Interdisciplinary collaboration including power systems, networked control, cyber-physical systems, and decentralized optimization.

- Project Contributions:
  - Decentralized Control Reference Architecture
  - Electricity Operating System: cyber-infrastructure for energy services exchange.
  - Decentralized Applications.
  - Foundations of an “Internet of Energy”

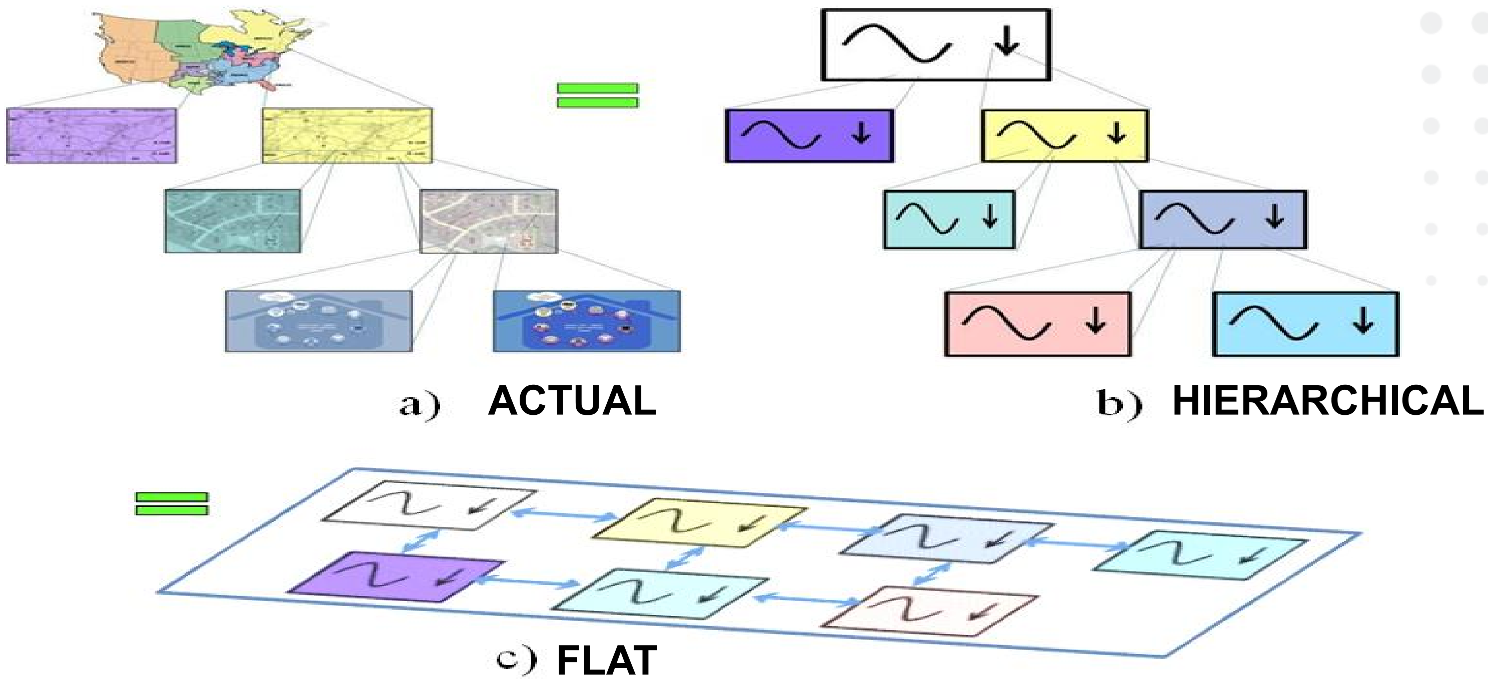
Outcomes: Architecture

Interconnection

ISO

Utility

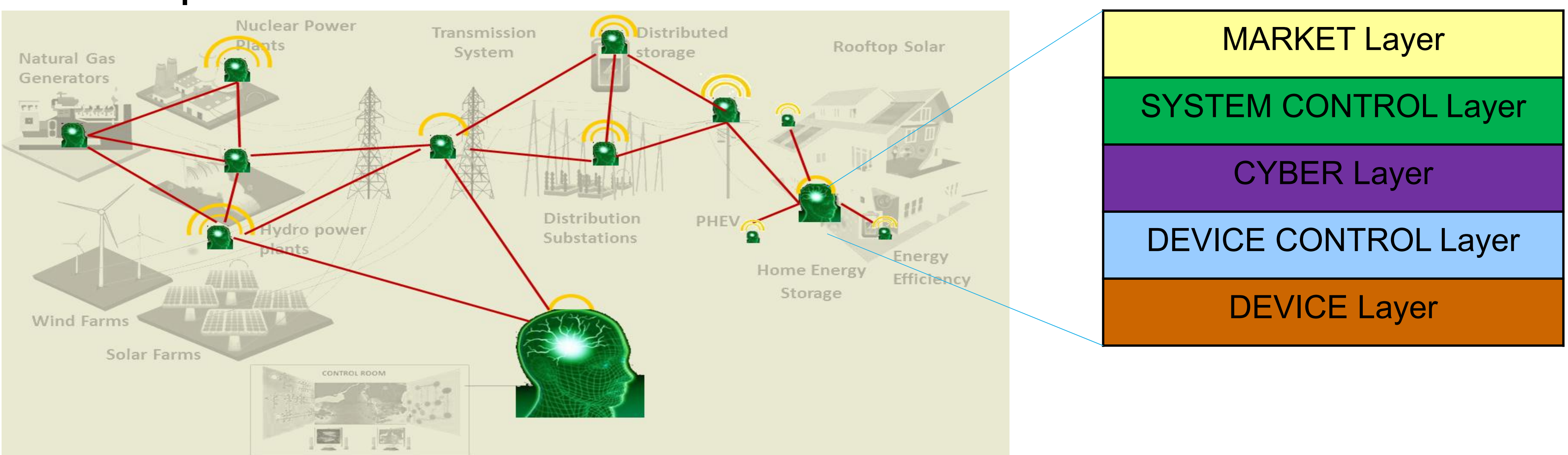
µGrid, Building, Home



1. A decentralized grid control and management architecture ***can scale massively*** and support many desirable use cases.
2. It is possible to organize and reconfigure the control scheme using hierarchical, flat, or hybrid arrangements.
3. Architecture is supported by formal cyber-physical paradigms.

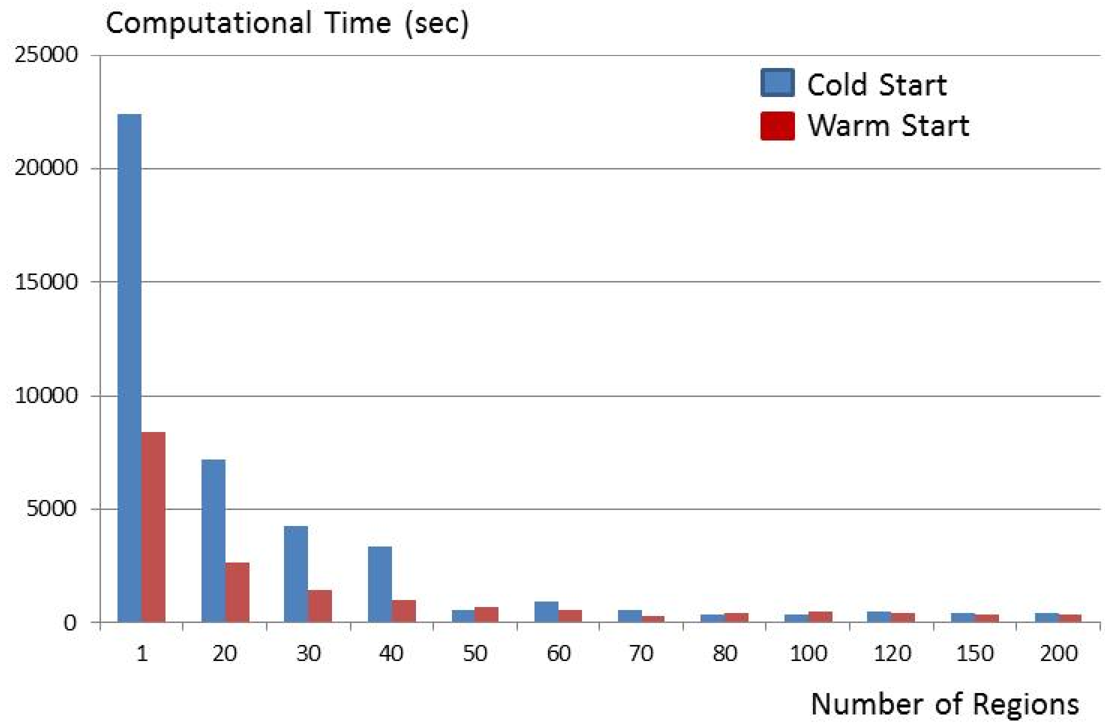
Outcomes: Decentralized Functionality

1. Subsystems (prosumers) at any scale can reach agreement related to power with local information and sparse data exchange.
2. Decentralized ***power agreement, frequency regulation, economic dispatch, unit-commitment and transfer capability*** was demonstrated using realistic large-scale transmission data.
3. Decentralized algorithms demonstrated ***better solutions*** compared to centralized methods.



Outcomes: Computational Performance

1. Computational performance of decentralized unit-commitment was two orders of magnitude faster than the centralized version, using actual ISO data (PJM).
2. A centralized organization can be arranged the computation in any number and structure of partitions. Same or better solution, much faster.
3. More importantly, decision-making can be massively decentralized by allowing smaller entities to make operational decisions.



ProsumerGrid, Inc.

- History
  - Under the “Energy Internet” banner, won DOE Clean Energy Business Model Competition.
  - Funded in July 2014
  - Graduate from NSF I-CORPs program (Fall 2014)
- Team:
  - Santiago Grijalva, Ph.D. Future Grid
  - Shabbir Ahmed, Ph.D. , Decentralized Stochastic Optimization
  - Magnus Egerstedt, Ph.D., Networked Control
  - Umer Tariq, final year Ph.D. student, Cyber-Power Co-Simulation
  - Marcelo Sandoval, MBA, final year Ph.D. student, Controls
  - John Higley, MBA, former Deloitte utility practice partner

Products in Development

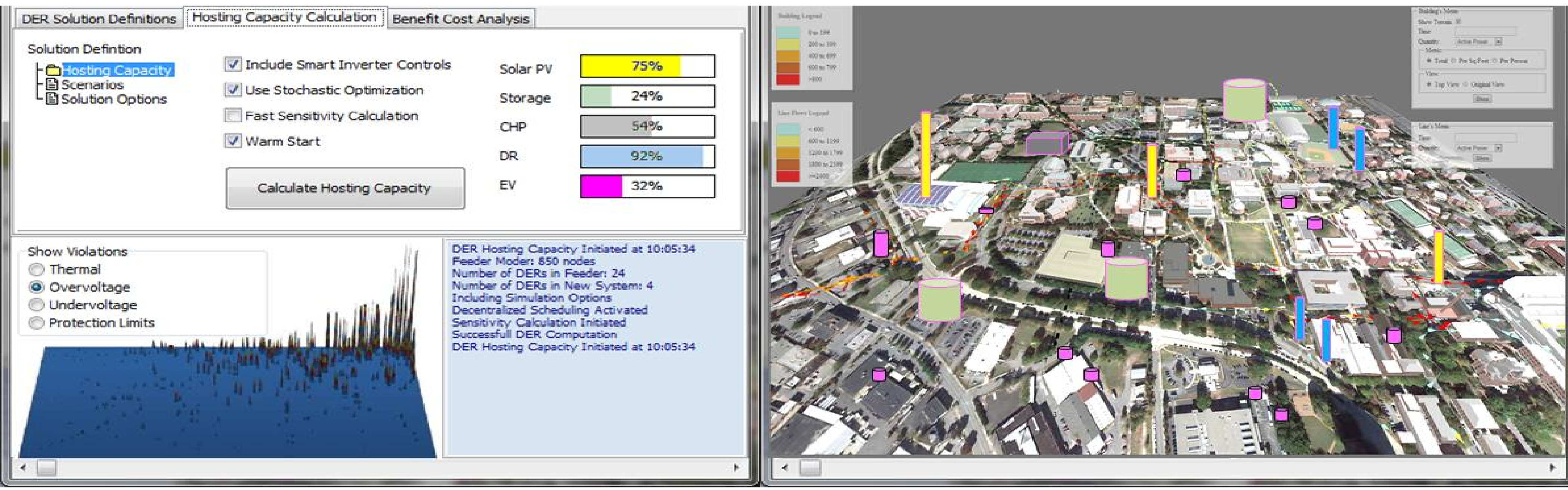
1. Distribution System Operator (DSO) Simulator

A powerful, yet easy to use software system that can simulate the complex emerging grid.

- Natively decentralized model.
- Natively suitable for distributed computing
- Based on new solvers: OpenDSS, GridLab-D.
- Overlay a powerful decentralized optimization layer
  - To handle renewable forecasting, storage, and flexible loads
  - To handle any number of high complex subsystems.
- Add a time-space “navigational” visualization engine
- Add economic/finance/business analytics module.

Simulation Example: DSO Simulator

- Technology: back-end parallel computation based on a spatio-temporal decentralized energy scheduling algorithm.
  - Able to capture in detail multi-agent (Prosumer) services definitions including energy, reserve, demand response, virtual services, etc.
  - Design of DSO/DSP Market Rules coupled with scheduling
  - Analytics for economic and financial evaluation.



Products in Development

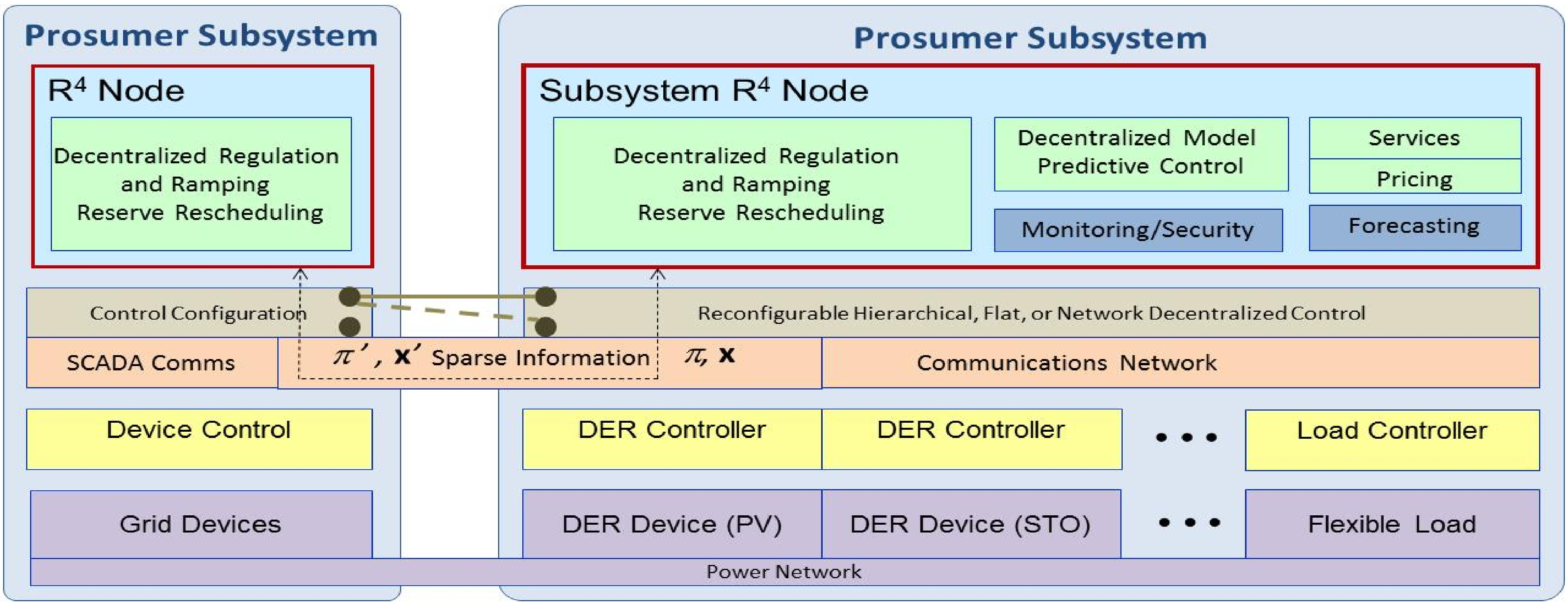
2. Real-Time Decentralized Energy Controller:

- Existing DMS systems are having serious problems evolving to meet the needs of the emerging grid.
  - Applications are fundamentally centralized, deterministic, single processor, snapshot-based, not suitable for emerging operations.
  - Very difficult to rapidly change existing code.
  - Impossible to scale to massive number of subsystems.
  - Do not provide formal protocols for exchange with prosumers.

- ProsumerGrid wants to develop a scalable ***Decentralized Energy Control System*** able to control and manage electricity networks using mathematically-proven, decentralized control algorithms.
  - Natively decentralized model.
  - Natively suitable for spatially-distributed decision-making by arbitrary subsystems (utility, feeders, feeder segments, microgrids, buildings, homes, etc.)

Real-Time Decentralized Controller

- Additional Project Features
  - Reconfigurable control structure.
  - Zero-cost-of-anarchy decentralized algorithms.
  - Massively Scalable.



Thanks

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