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Grand Challenge Microgrid Project Overview

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Energy Security Program

Energy Security Roles

$250M DOE Energy Research Program

Support DoD on energy system, physical, and cyber security

System integrator for the DOE/NNSA

DoD Installation Security Projects

Energy Security Focus

Operational Energy Systems
- **Electric Power Assurance**
  - **Microgrid, renewables, nuclear, storage, control systems, cyber**
- **Transportation Energy Assurance**
  - **Combustion research, renewable fuels**

Climate Change Science
- **Operational Impacts**
- **Assessments**

Nuclear Design & Fuel Cycle

Combustion Research Facility

Distributed Energy Technology Laboratory

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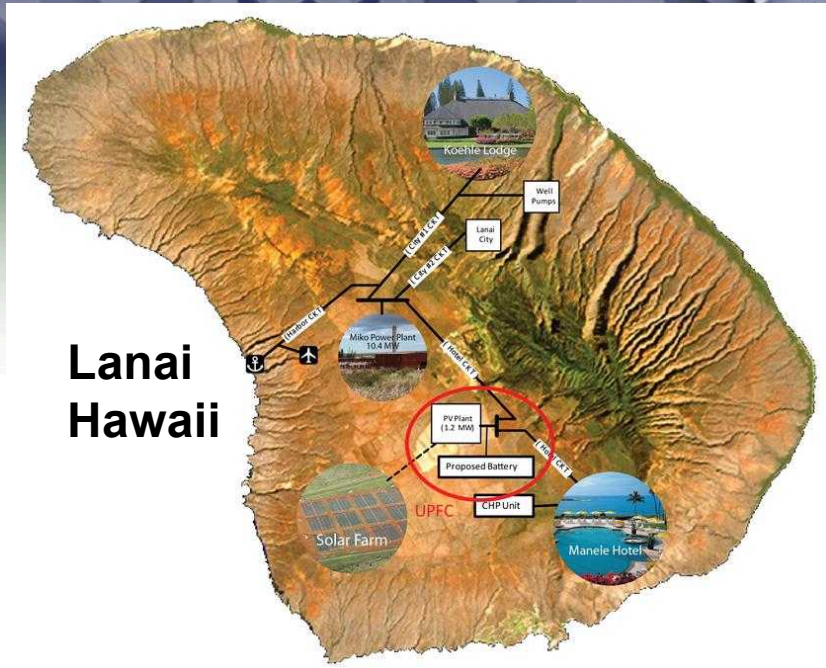
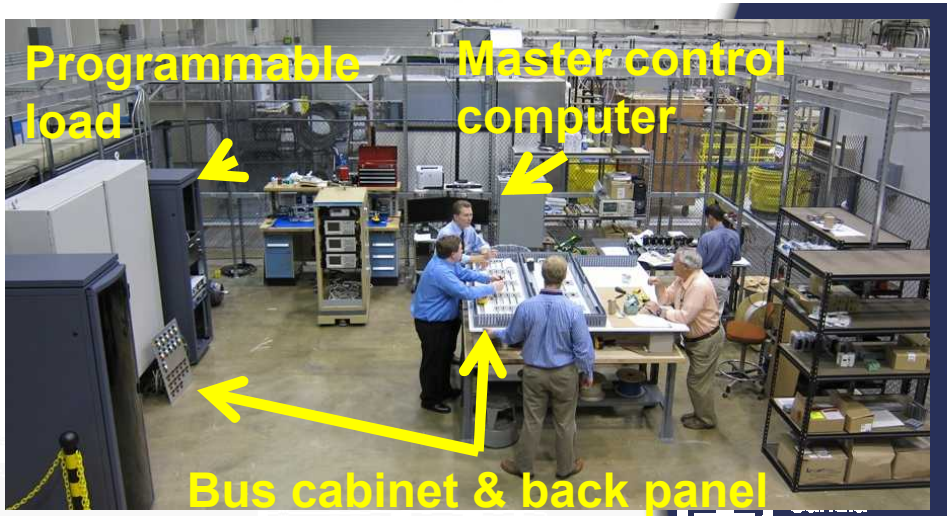
Networked, Secure, Scalable Microgrids (SSM ™) for Power Grid Architectures

- SNL is unlocking microgrid application space through ground breaking nonlinear control theory, informatics, and innovation.
- Tools are being developed for networked microgrids spanning from conventional to 100% stochastic generation.
- Potential impact
  - Unlimited use of renewable sources
  - Reduction in centralized fossil fuel based sources
  - Self-healing, self-adapting architectures
  - Microgrids as building blocks for larger systems





Construction of the SSM test bed

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Energy Challenge - Harvest, Transform, and Control Delivery of Available Energy

Energy & Material Resources

- Fossil (coal, oil, gas)
- Solar (including wind and hydro)
- Geothermal
- Nuclear
- Plant, animal, and human waste
- CO_2 & other energy conversion byproducts

Energy Processing

Harvest, transform, and deliver exergy* at the necessary amount and rate.

Energy Needs or Services

- Electricity
- Fuel
- Heat
- Cooling
- Chemicals (such as lubricants)
- Clean Water

***EXERGY = AVAILABLE ENERGY = useful portion of energy that allows one to do work and perform energy services**

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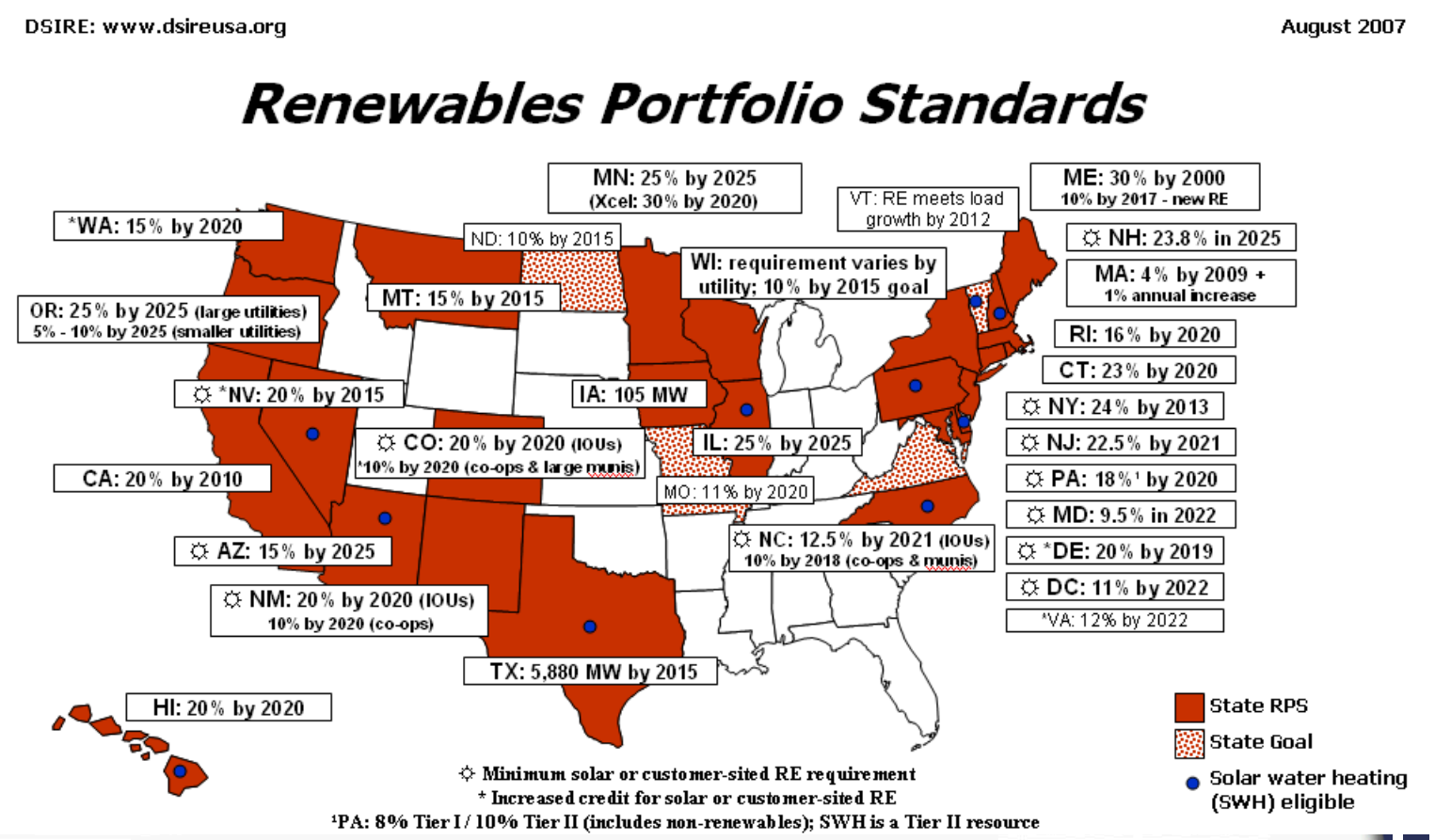
An Emerging Market:
Preparing for Large-Scale Renewable Energy Integration

New Market Scenario: **Climate change concerns, renewable portfolio standards, incentives, and accelerated cost reduction driving steep growth in U.S. renewable energy system installations.**



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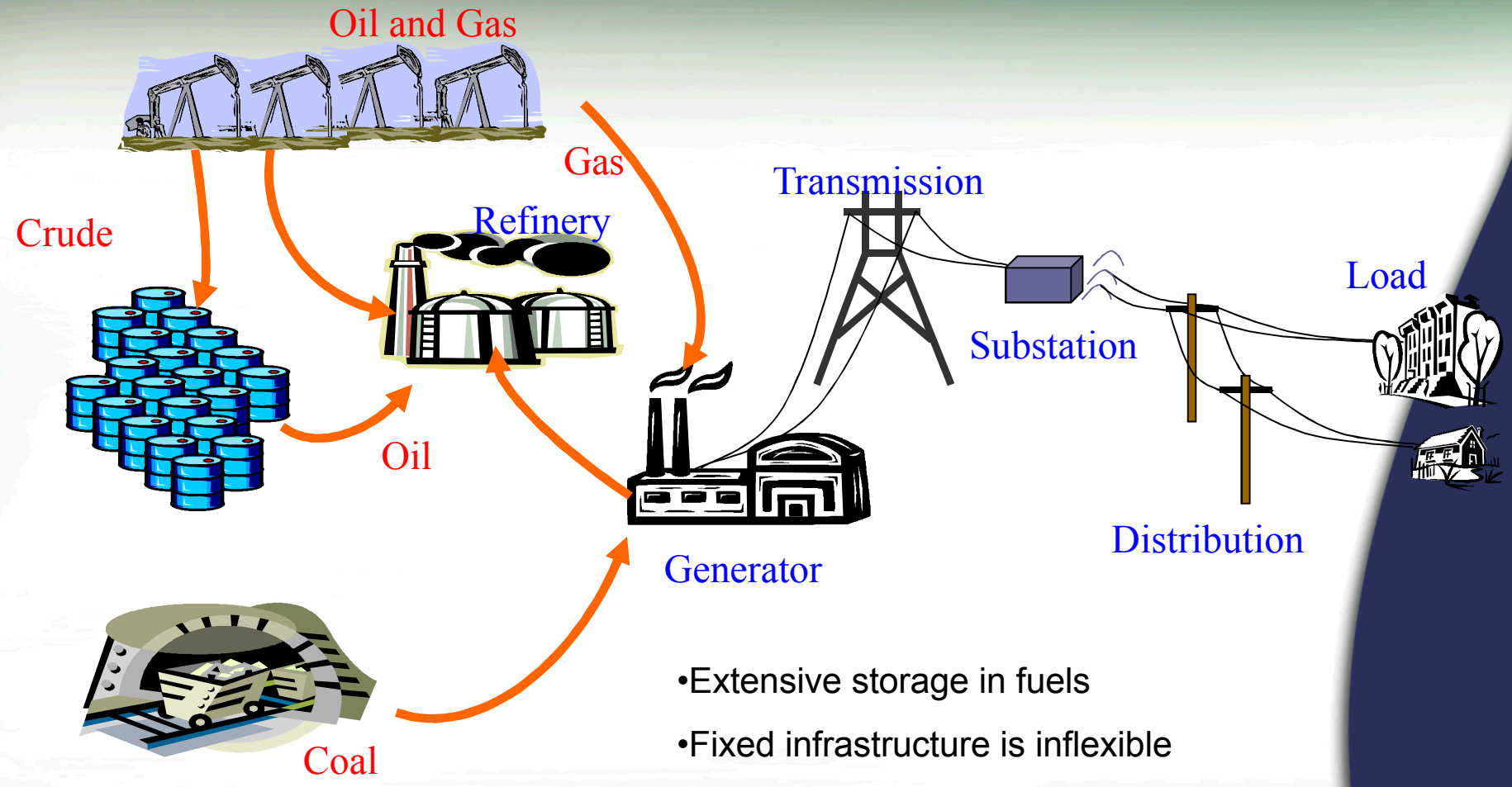
Today's Power Grid is Designed for Dispatchable Centralized Generation

Controlled Supply | **Fixed Infrastructure** | **Random Load**



- Extensive storage in fuels
- Fixed infrastructure is inflexible
- Significant human interaction

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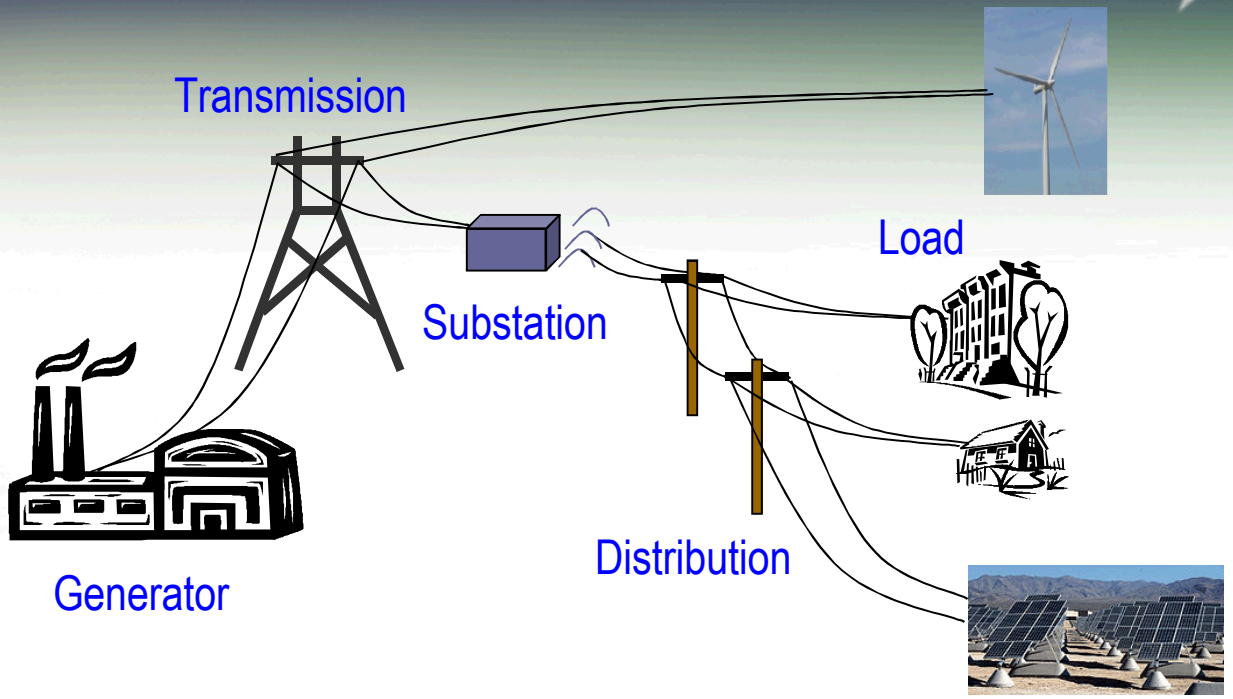
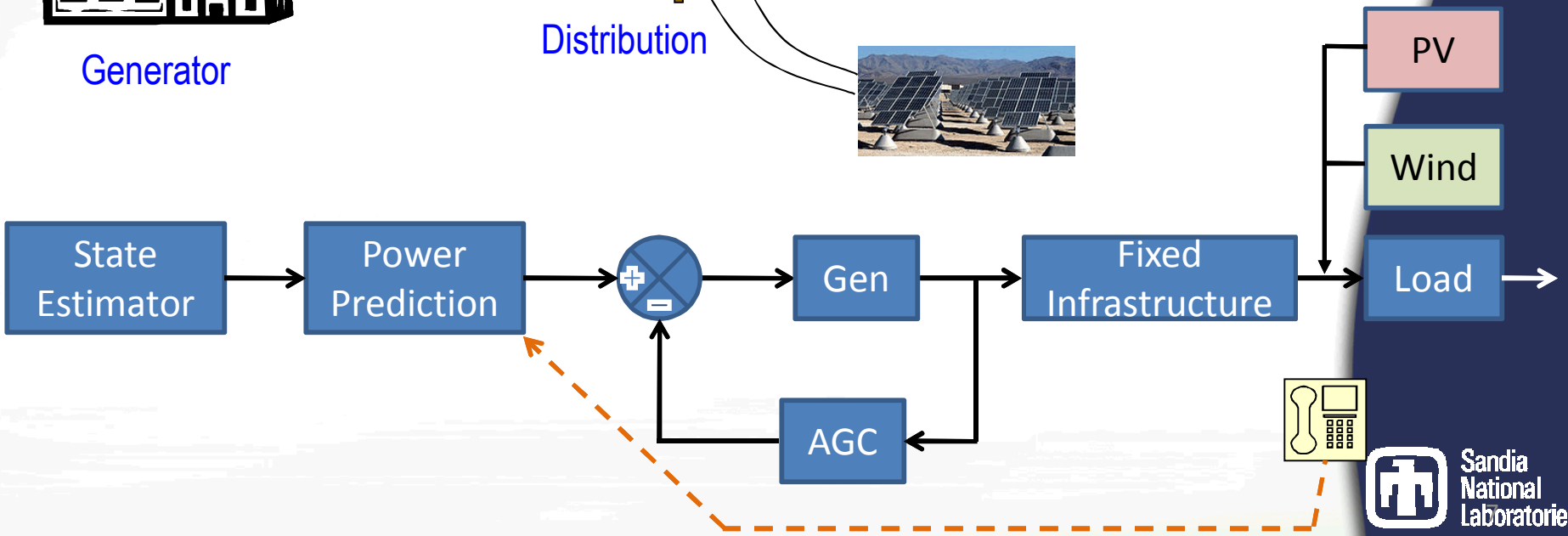
Today, Stochastic Renewable Sources are Treated as Negative Loads





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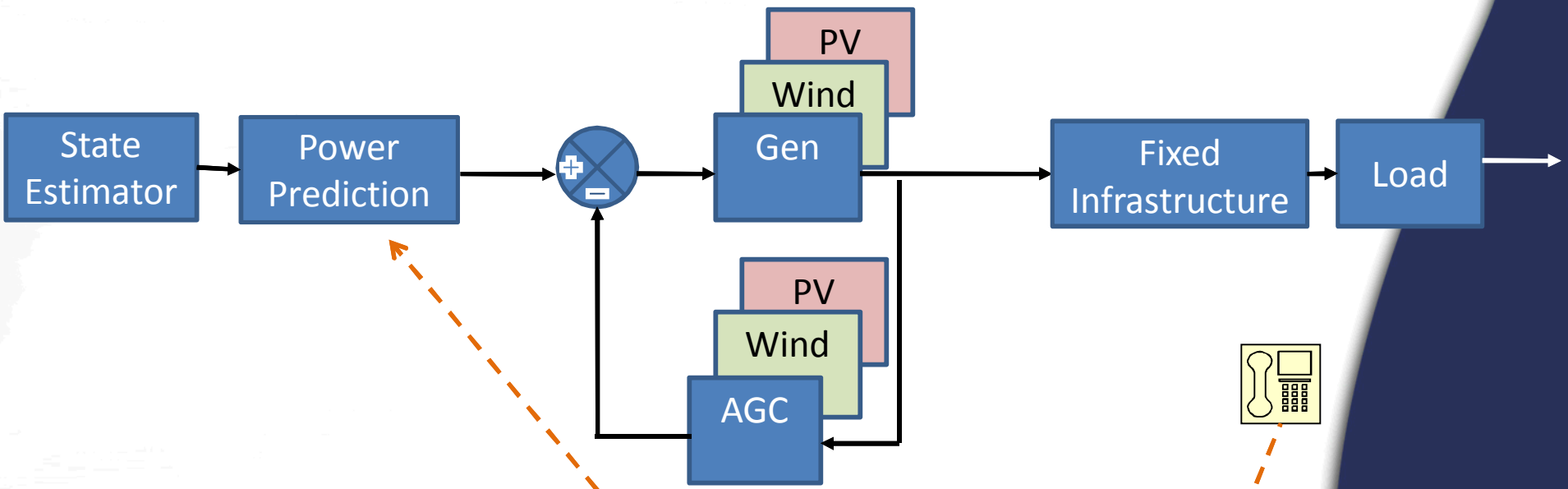
To Achieve Maximum Benefit Renewable Energy Needs to be Treated as a Source

System efficiency can increase with reduction in excess generation capacity.



Both our generation and our loads are now random!

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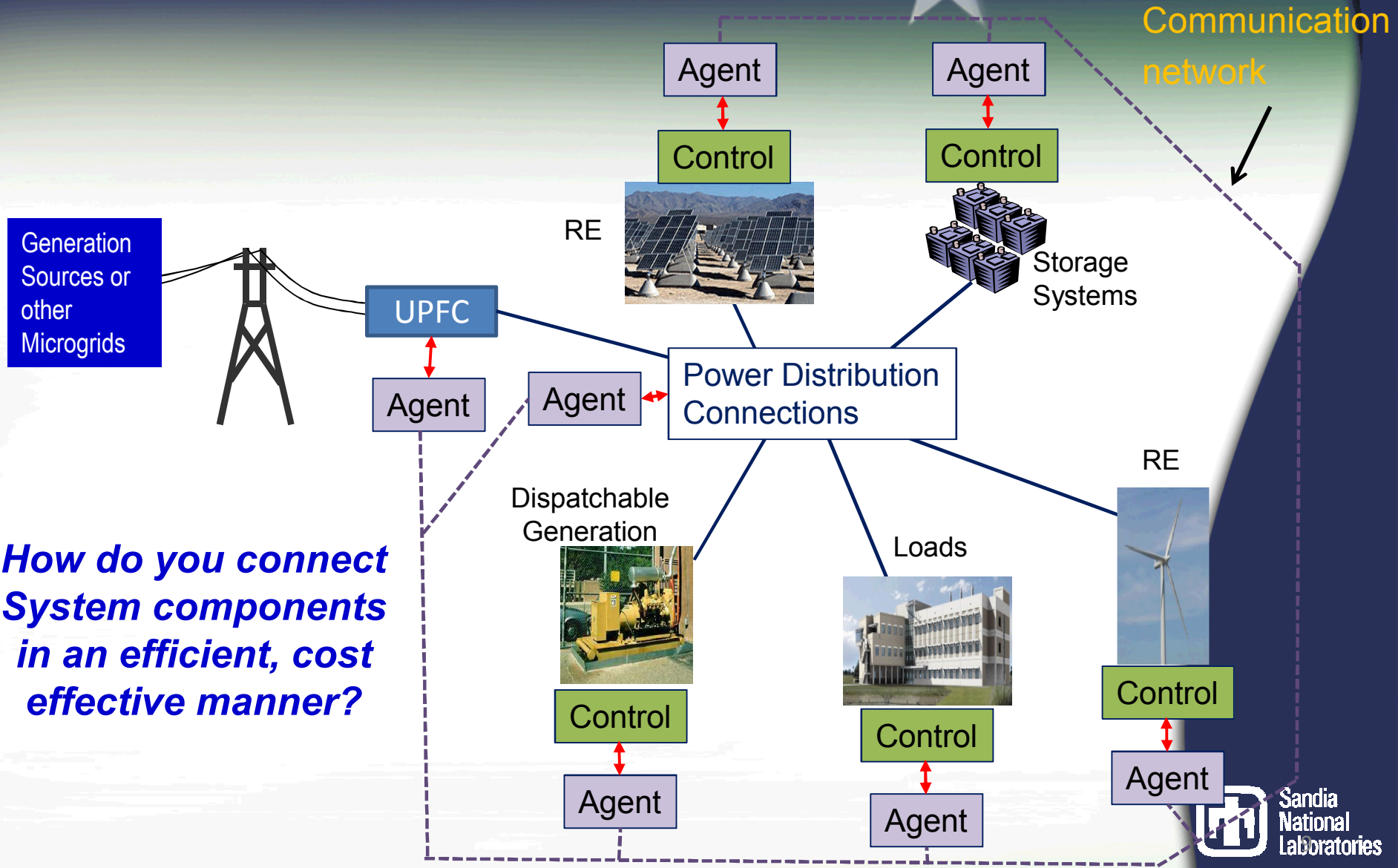
A Highly Interconnected Microgrid Will Result from these Advancements



How do you connect System components in an efficient, cost effective manner?

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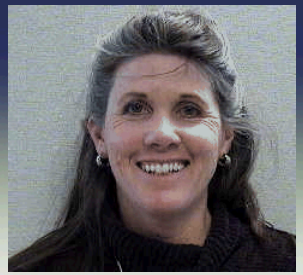
The SSM Technical area leads



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Champion

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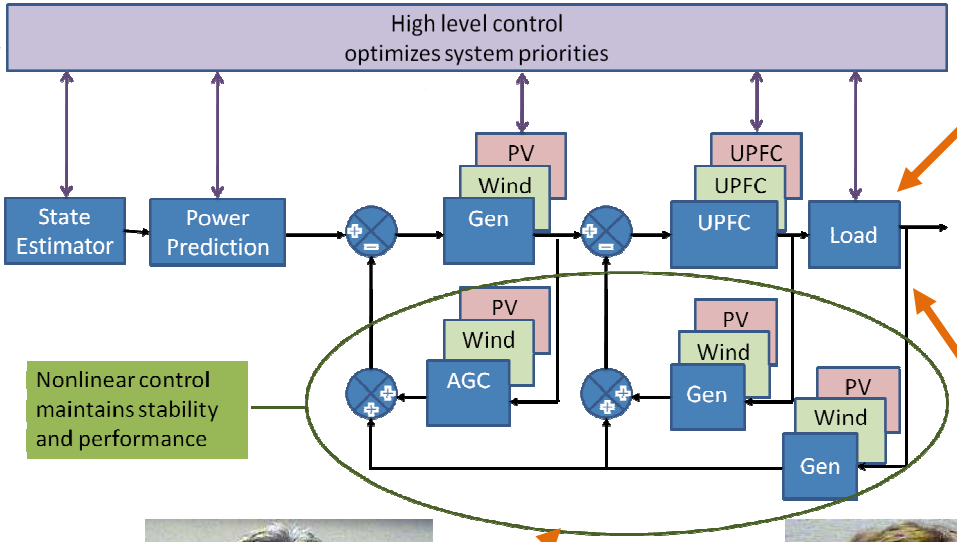
Principal investigator

Marvin Cook
Informatics/Agents

Jason Neely
Hardware,
Modeling, &
Simulation



David Wilson
Nonlinear Controls

Tony Lentine
Communications

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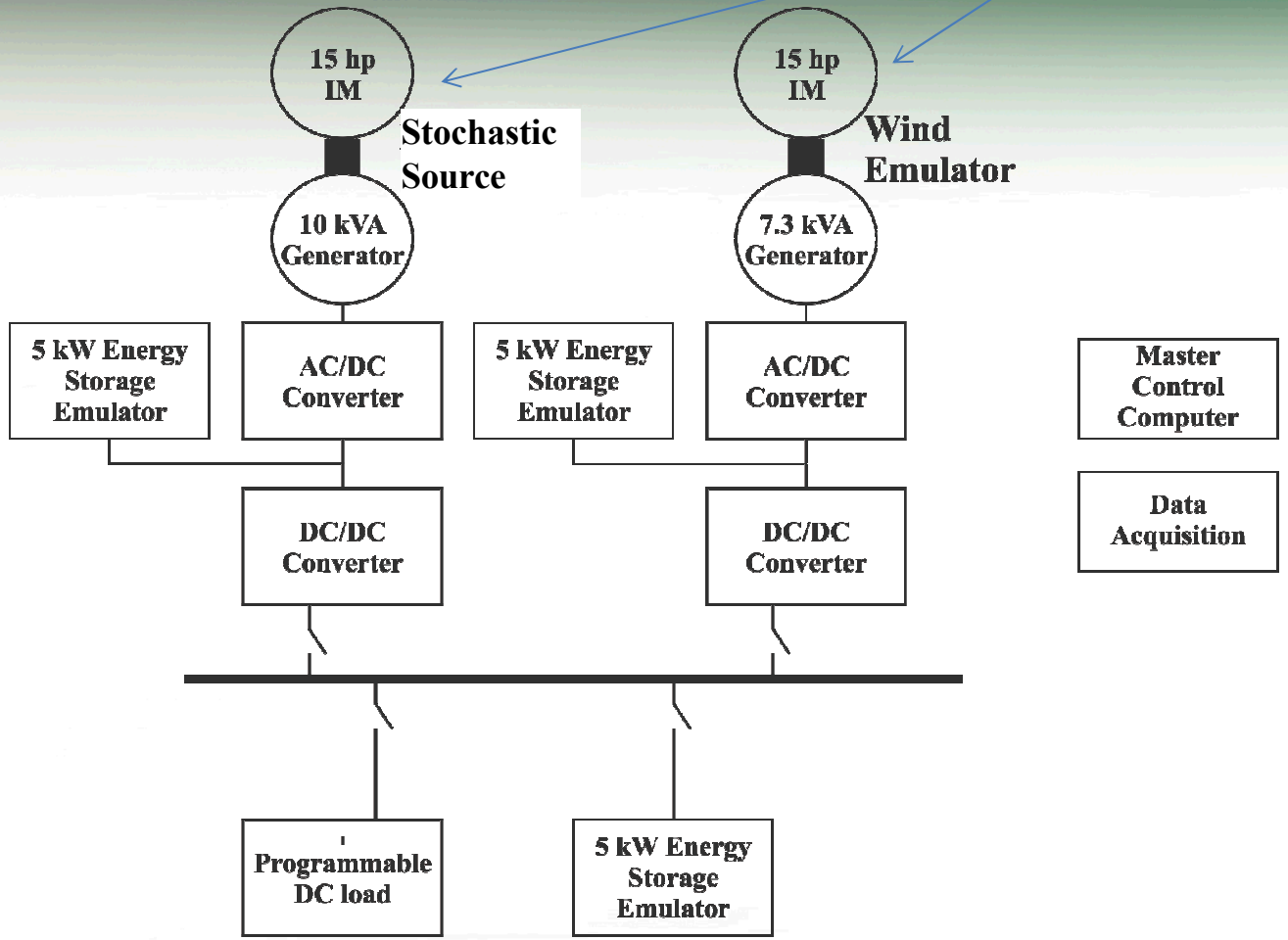
SSM Test Bed Experiment Configuration 2

Sources
2 - Stochastic



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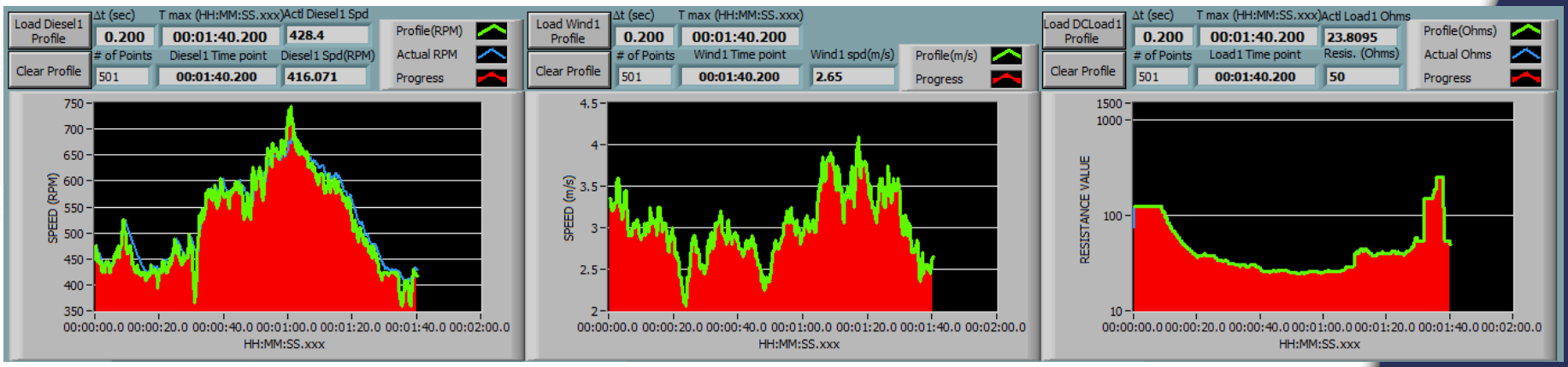
Hamiltonian Based Control Approach with Full State Control - Hardware Results Config. 2

Source and load profiles

Stochastic source 1

Stochastic source 2

Load



Green – commanded profile
Blue – actual profile
Red – indicates progress in time

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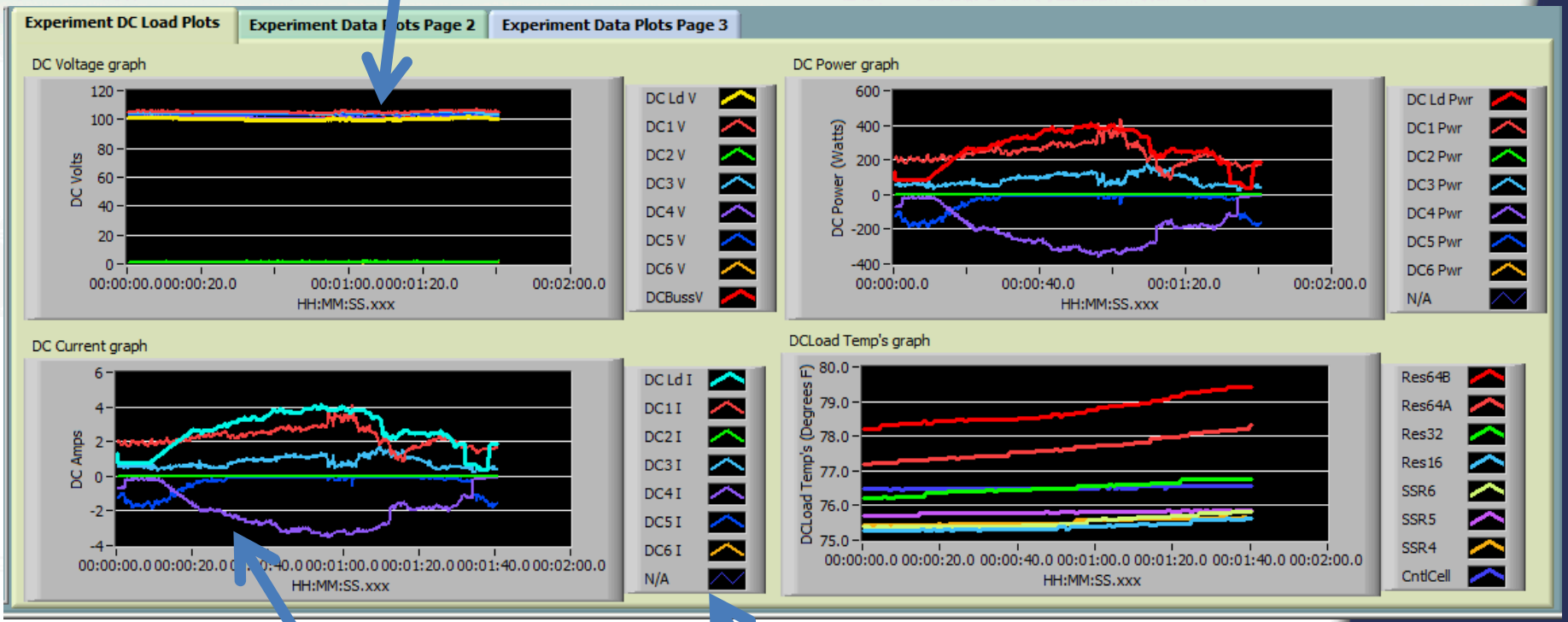
Hamiltonian Based Control Approach with Full State Control - Hardware Results Config. 2

Bus voltage regulation is does not oscillate

Lack of oscillations indicate that the sources in the system are working in unison.



Source and load currents indicate system energy balances

Cyan – load current

Red – diesel current

Light blue – wind current

Purple – load current

Dark blue – Bus energy storage current

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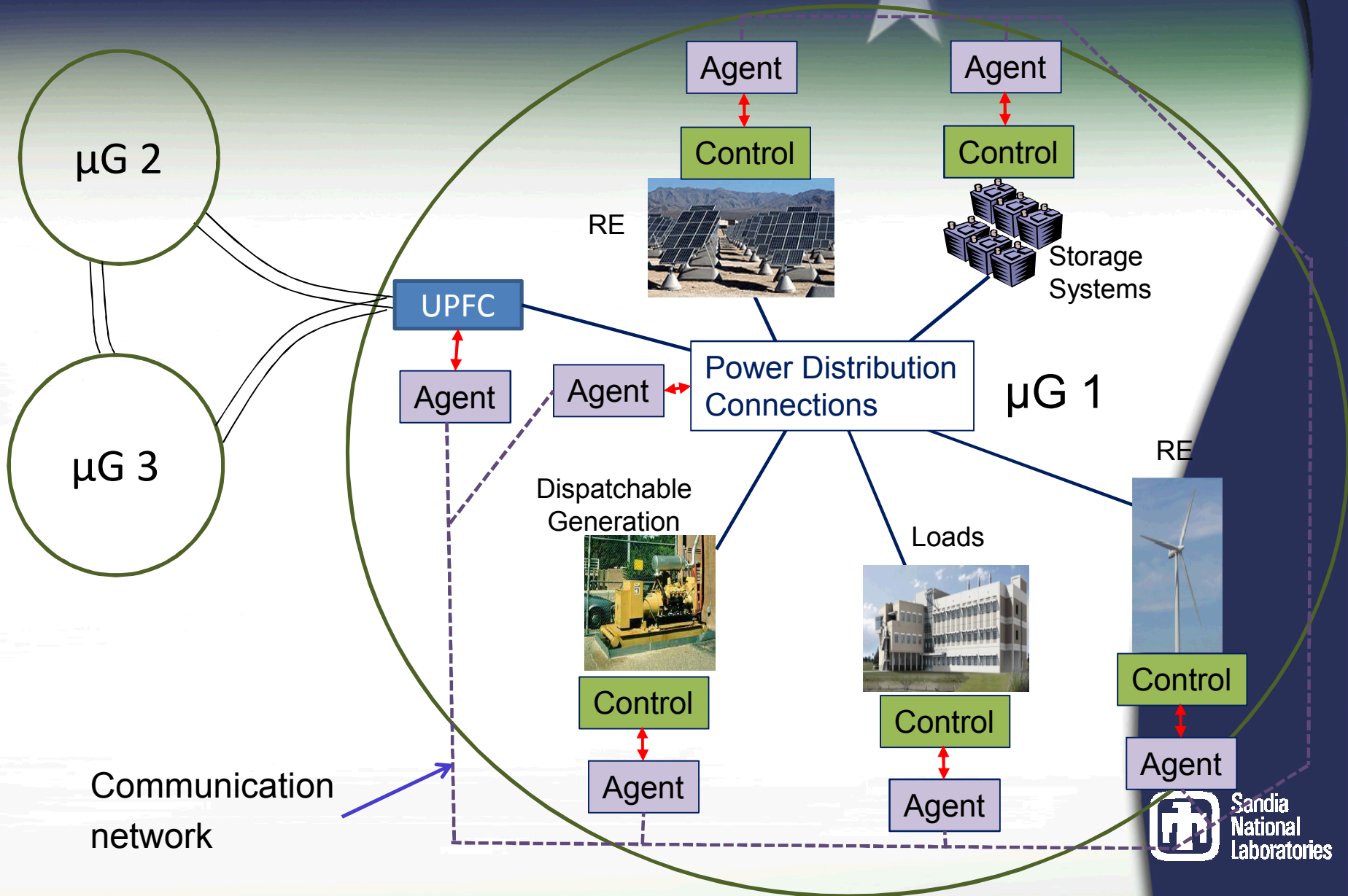
These Microgrids will be Building Blocks for Large Networks



In Summary

- **New design and analysis techniques are being developed through the integration of:**
  - Hamiltonian based control theory
  - Informatics theory / agents
  - Power electronics systems theory
  - Cyber security
  - Communications
- **100% random generation has been demonstrated**
- **Scalability is of our techniques is the focus of the third year**

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