Microgrid Controller Requirements

Mark McGranaghan
Electric Power Research Institute

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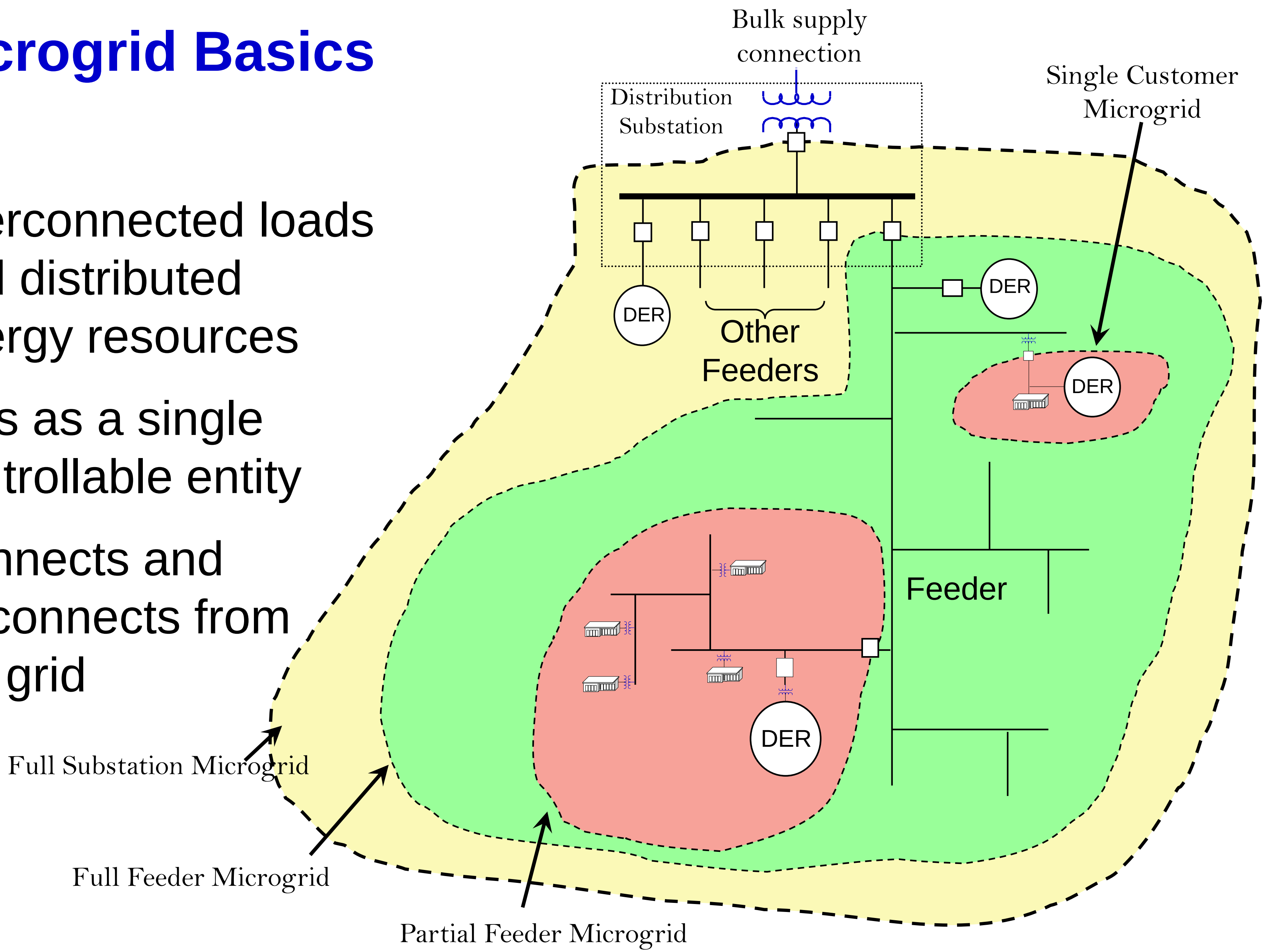
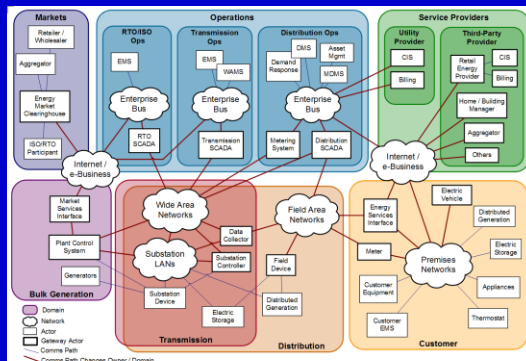
- EPRI members generate more than 90% of the electricity in the United States
- International funding of more than 18% of EPRI’s research, development and demonstrations
- Programs funded by more than 1,000 energy organizations

Microgrid Basics

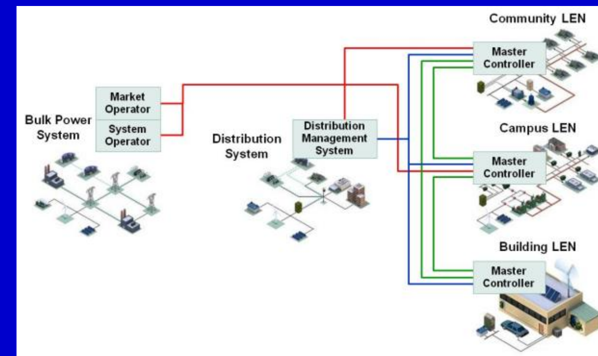
- Interconnected loads and distributed energy resources
- Acts as a single controllable entity
- Connects and disconnects from the grid



Challenges for the next generation power system – microgrids part of all these challenges

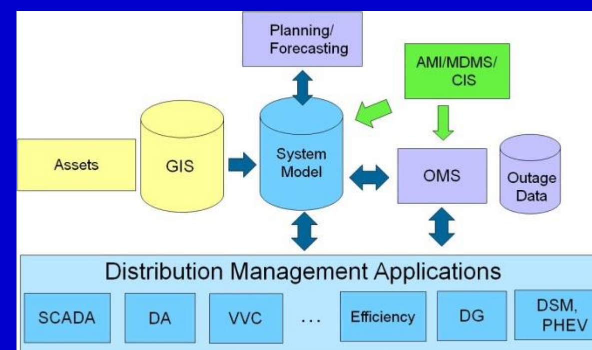


Architecture and Interoperability



Distributed Controls Integration

Monitoring, Sensors, and Data



Model Based Management

Challenges and R&D Needs Cut Across All Levels of the Grid

Microgrids as part of Resiliency Strategies

- Expanding T&D expensive and difficult
- Hardening of grid very expensive
- Local resiliency sources can be very strategic

Hardening Measures	Recovery Measures	Survivability Measures

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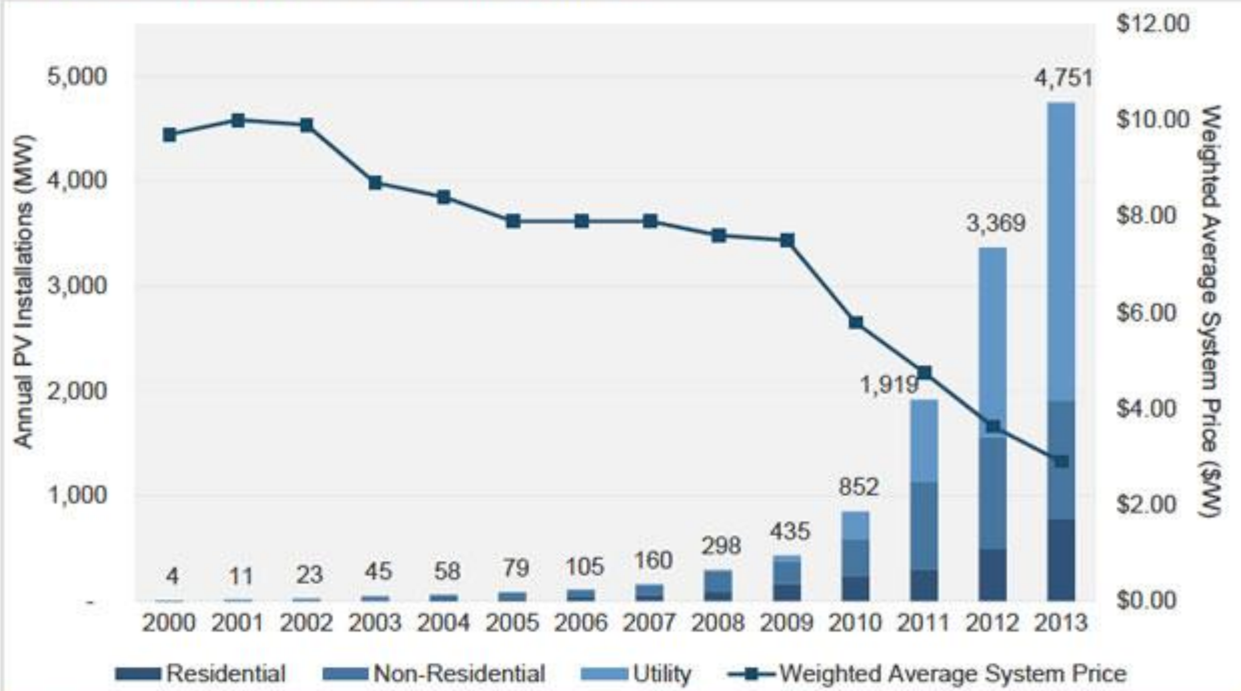
Microgrids and PV

Figure 2.1 U.S. PV Installations and Average System Price, 2000-2013



Installations (MW)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Residential	1	5	11	15	24	27	38	58	82	164	246	304	494	792
Non-Residential	2	3	9	27	32	51	67	93	200	213	339	831	1,072	1,112
Utility	0	3	2	3	2	1	0	9	16	58	267	784	1,803	2,847
Total Installations	4	11	23	45	58	79	105	160	298	435	852	1,919	3,369	4,751

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Smart Inverter Technology

DC Power ***AC Power***

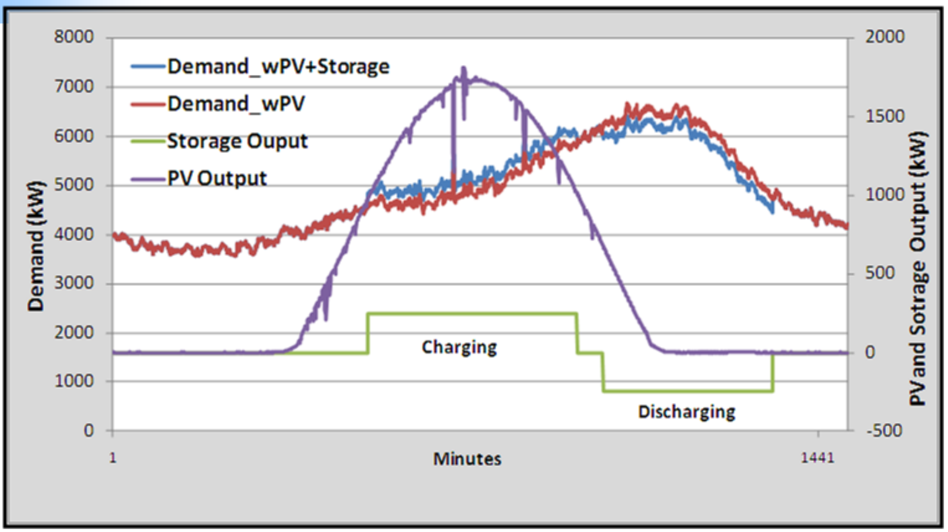
Traditional Inverter Functionality

- Matching PV output with grid voltage and frequency
- Providing safety by providing unintentional islanding protection
- Disconnect from grid based on over/under voltage/frequency

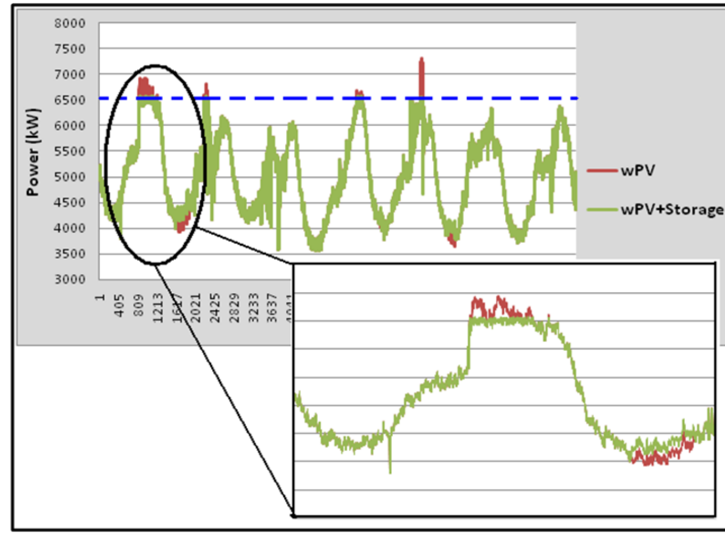
Smart Inverter Functionality

- Voltage Support
- Frequency Support
- Fault Ride Through (FRT)
- Communication with grid

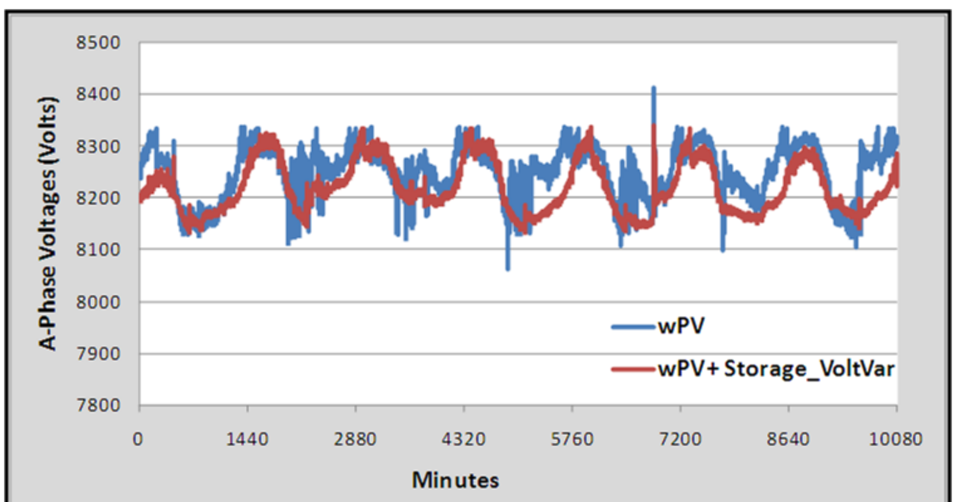
Energy Storage has many functions



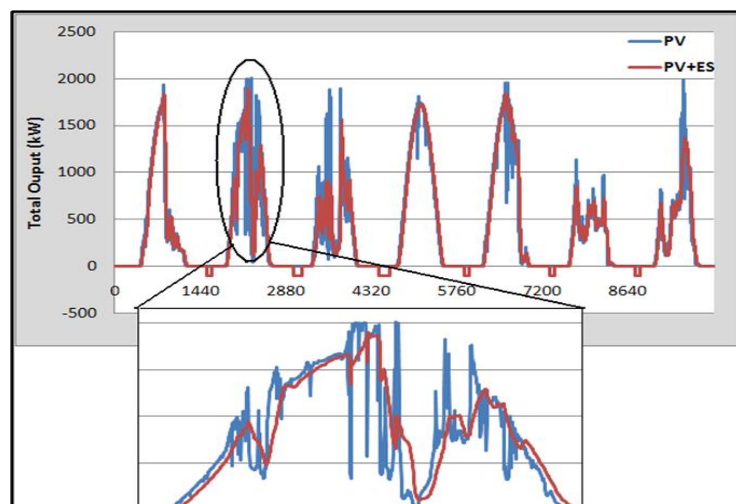
Load Shifting



Peak Shaving



Voltage Control



PV Smoothing

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Electric Vehicles and Smart Appliances can be part of the energy management

Microgrids are about Local Energy Optimization

The integrated grid allows **Local Energy Optimization** to become part of **Global Energy Optimization**.

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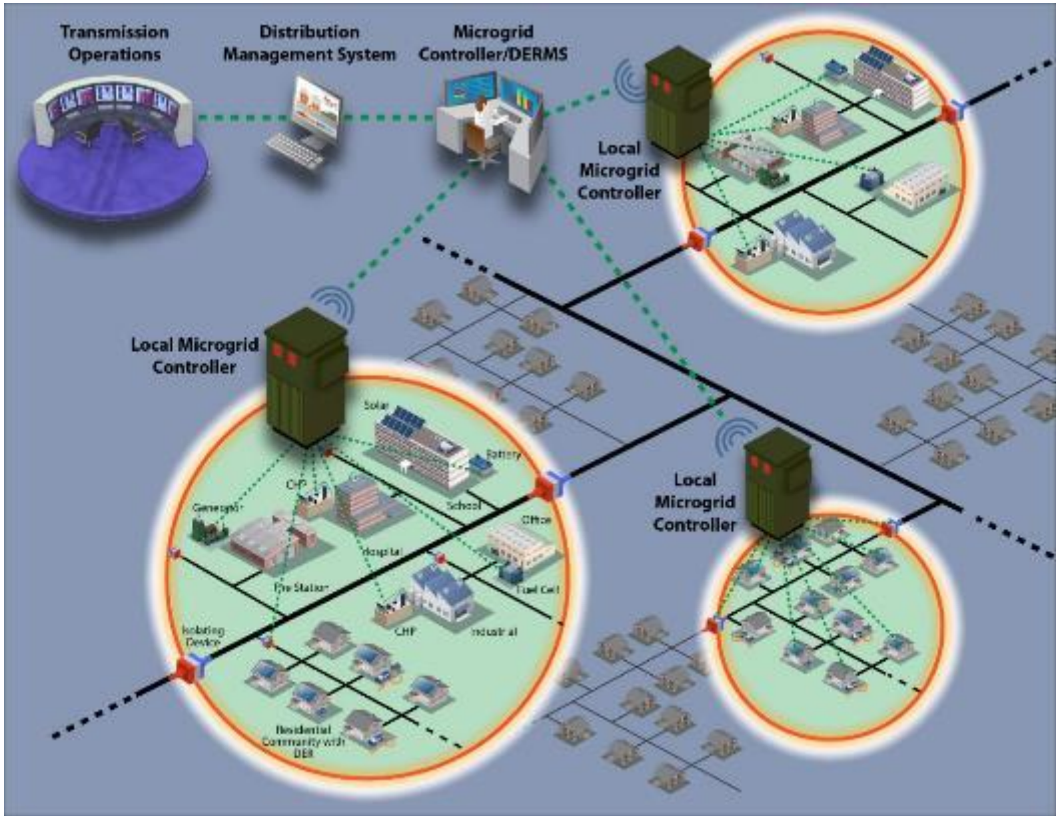
The Utility Challenge: Integration of Microgrids

Regulatory Challenges:
- Ownership of generation
- Administrative burden of regulation

Technical Challenges:
- Bi-directional power flows
- Fault current contribution
- Unit Level Volt/VAR support
- Islanded Operation

Economic Challenges:
- DG technologies still costly and with uncertain lifetimes
- Business model still undeveloped



Development of an integrated approach to microgrids opens many opportunities

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Microgrid Design Parameters

- Number of customers served
- Physical length of circuits and types of loads to be served
- Voltage levels to be used
- Feeder configuration (looped, networked, radial)
- Types of distributed energy resources utilized
- AC or DC microgrid
- Heat-recovery options
- Desired power quality and reliability levels
- Methods of control and protection

	Urban Utility Microgrids	Rural Utility Microgrids	Non-Utility Microgrids	Remote / Island Microgrids
Application	Downtown Areas	Planned Islanding Load Support	Commercial / Industrial Clusters University Campus Residential Development	Remote Communities and Loads Geographical Islands
Main Drivers	Improved Reliability; Outage Management; Renewable and CHP Integration		Reliability and Power Quality Enhancement; Energy Efficiency;	Electrification of Remote Areas
Benefits	Improved Reliability; Fuel Diversity; Congestion Management; Greenhouse Gas Reduction; Upgrade Deferral; Ancillary Services		Premium Power Quality; CHP Integration; Demand Response Management	Supply Availability Integration of Renewables
Grid-Connected	Primary Mode of Operation		Primary Mode of Operation	Never
Intentional Islanding	Nearby faults or System Disturbances Approaching Storms		Nearby faults or System Disturbances Times of Peak Energy Prices Approaching Storms	Always Islanded

Source: Johan Driesen and Farid Katiraei, "Design for Distributed Energy Resources," IEEE Power & Energy Magazine, May/June 2008

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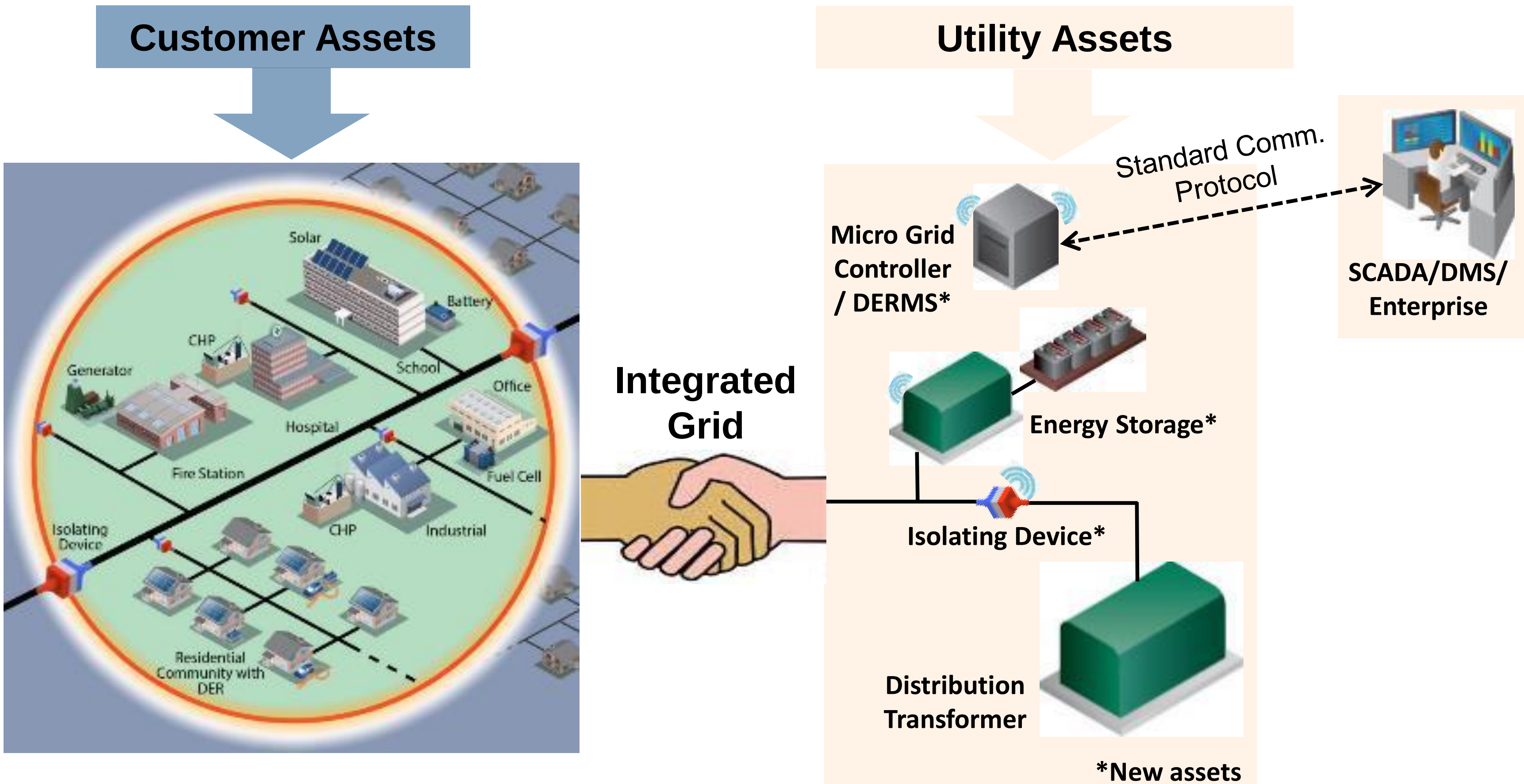
One option –
Integrating Customer DER with Utility Assets



Grid Interactive Microgrid Controller for Resilient Communities

- **Objective**: Develop, configure, test utility-ready, open standard-compatible microgrid controller
- **Period of Performance**: Sept 30, 2014 – Sept 30, 2016
- **Microgrid Controller Requirements**
  - Standardized & Scalable
  - Customizable and Interoperable
  - Consistent Implementations support integration
- Three-Tiered Testing and Evaluation

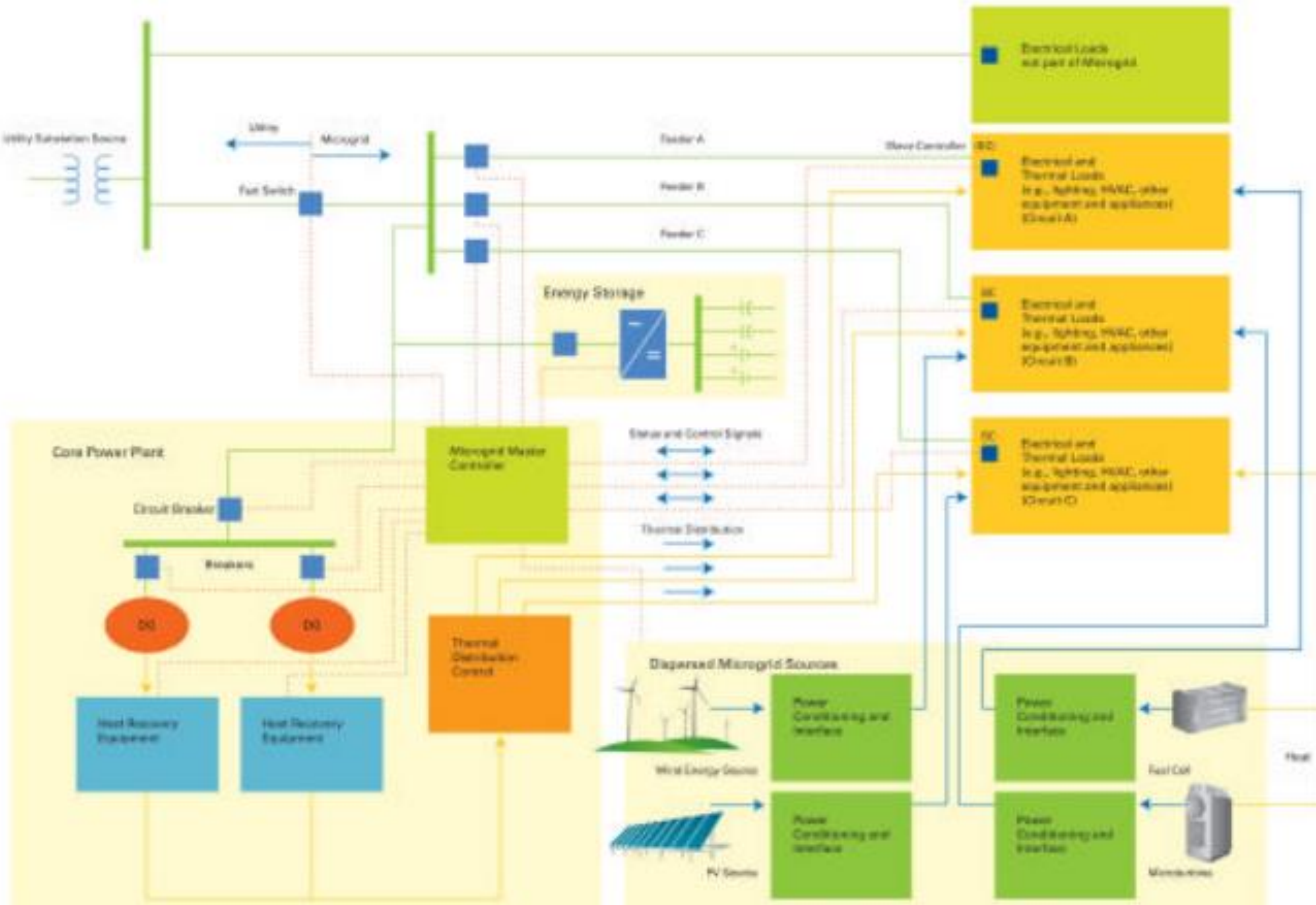
Utility Participants and Target Sites

- Central Hudson Gas & Electric
- New York Power Authority
- National Grid
- Orange & Rockland
- United Illuminating
- Duke Energy
- Entergy
- Tri-States G&T
- Southern Company
- TVA
- PEPCO
- Public Service of New Mexico
- Hydro Quebec
- Xcel

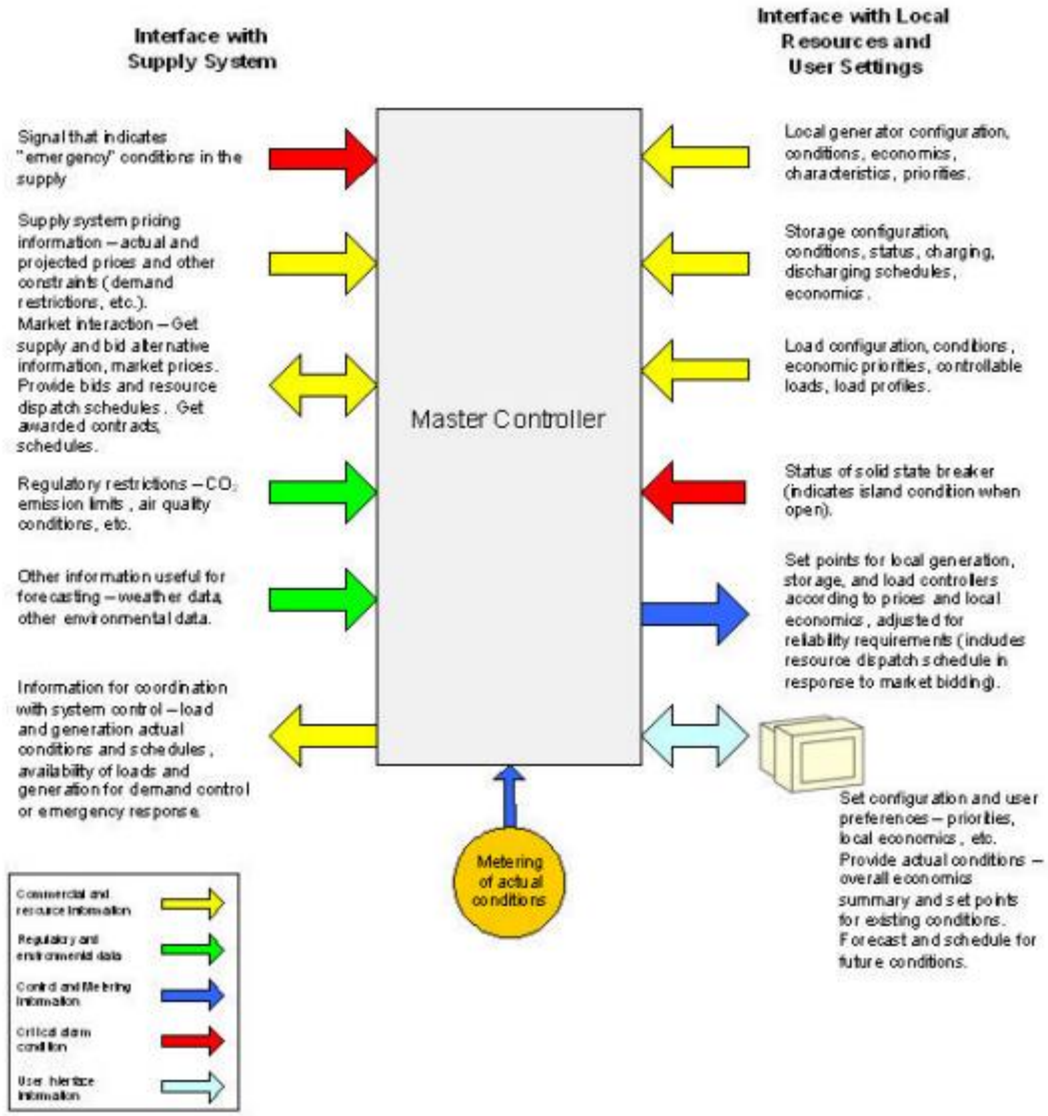
Target Communities

- Bridgeport, CT
- Woodbridge,CT
- Buffalo Niagara Medical Campus

Controller Requirements



Modes of Operation



Mode 1 – **Connected to the Grid** (Local Energy Optimization Mode)

Mode 2 – **Emergency Mode** Connected to the Grid (Operation to Support Grid)

Mode 3 – **Islanded Mode** (Optimization of Supply to Critical Loads)

Microgrid Technical Challenges : Protection

- Not enough short-circuit current in Microgrid mode for protection to sense and operate
  - Voltage-based protection was recommended : No need for multiple settings group to support grid or islanded operation
    - May require additional equipment and change in protection settings.
- Insulation coordination could be an issue
- Microgrid operation may result in loss of effective ground reference

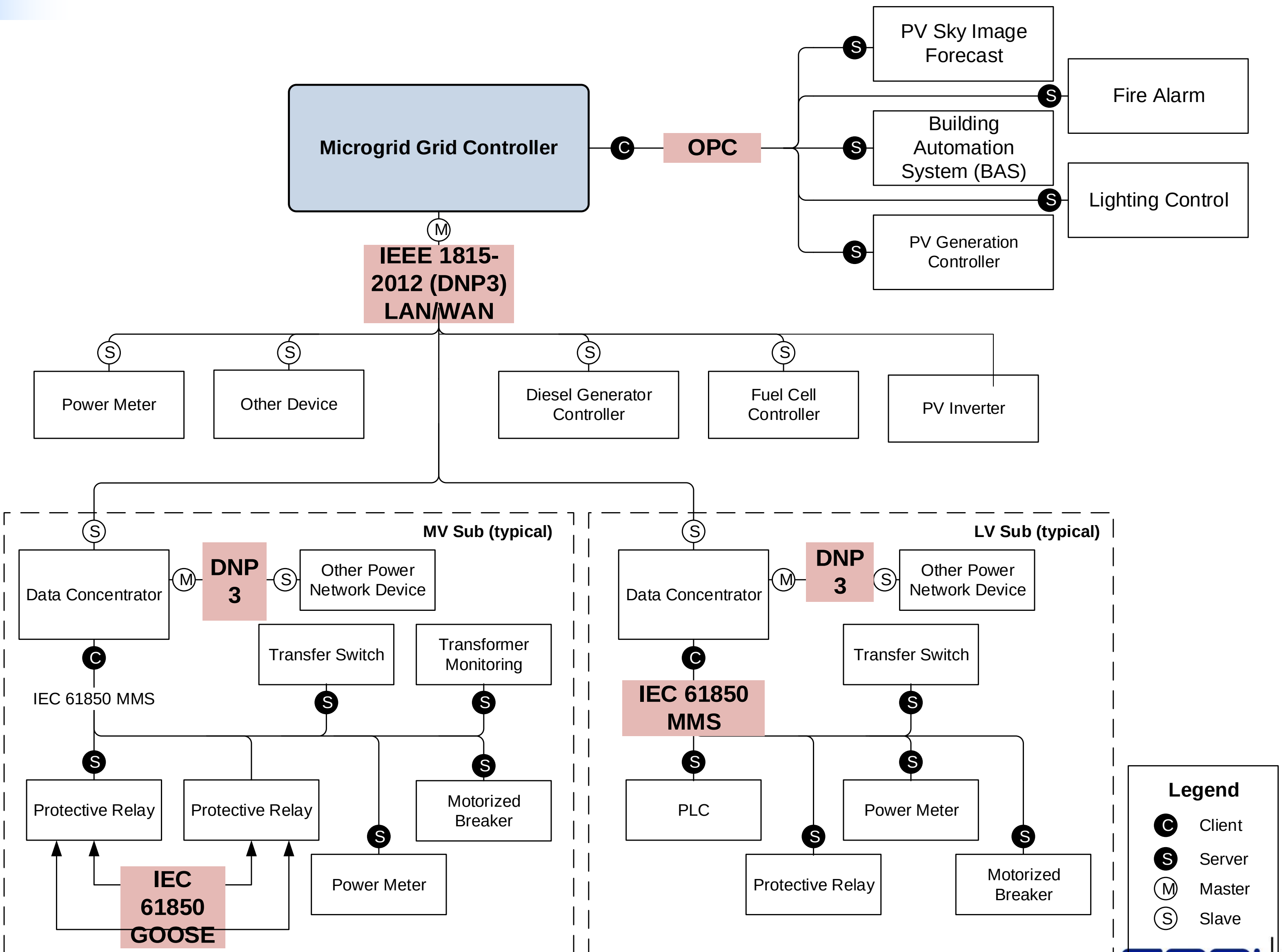
Keeping protection scheme simple translates into improved dependability as well as much simpler analysis in the event of misoperation

Use Cases and Functional Requirements

Requirements	Use Case	Scenario	Step
Sensors shall transmit status to the Microgrid Controller.	2	1	1
If the microgrid cannot support the estimated critical facility maximum load, then the Microgrid Controller shall issue an alarm to the operator.	2	1	2
If the monitored frequency within the microgrid falls outside of the pre-specified range, Microgrid Controller shall generate an alarm to the operator.	2	1	3
If the voltage has been outside of the pre-specified limits for longer than the predefined time period, Microgrid Controller shall increase or decrease on-site energy supply as required to bring the voltage to within the pre-specified range.	2	2	2
If the voltage has been outside of the pre-specified voltage limits for longer than the predefined time period, Microgrid Controller shall generate an alarm to the operator.	2	2	3

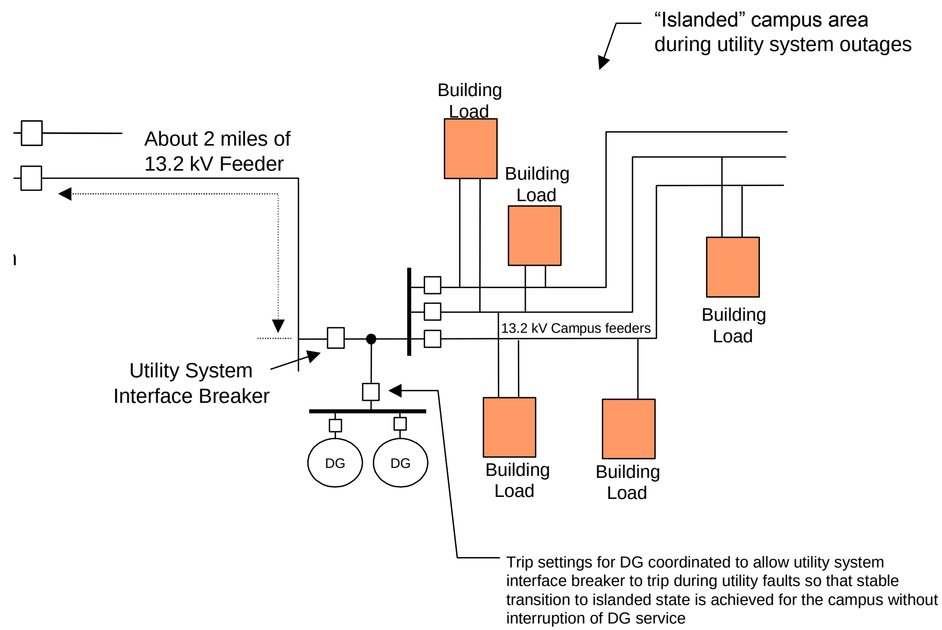
Use Case Scenario	*Information Producer*	*Information Receiver*	*Name of information exchanged*
3.1	SCADA System	Operator, Microgrid Controller	Critical circuit status - switchgear status (open/closed)
3.1	Generator	SCADA System	Critical circuit status – generator state (off, pre-armed, armed, generating)
3.1	Automated Switch	Operator, SCADA System	Critical circuit status – generator state (off, pre-armed, armed, generating)
3.1	Operator	SCADA System	Commands to devices in the critical circuit

Communication Protocols and Requirements



Feasibility Assessments – Utility Compatible Grid Interactive Communities

- Identify scope/attributes for microgrid community
- Identify the need, objectives, and benefits
- Identify amount and type of generation mix
- Identify islanded operation modes
- Identify loading conditions, critical load identification, DER types, advanced grid support functions, coordination & control strategies
- Identify any EE and DR options
- Identify infrastructure upgrades
- Identify the tool for the evaluation
- Conduct analysis
- Evaluate range of options



Taking an Integrated Grid Approach

- Customized feasibility studies
- Utility specific Technical/Economic analysis

Working Towards an Integrated Grid