Microgrid Control Integration

To Maximize Performance and Value

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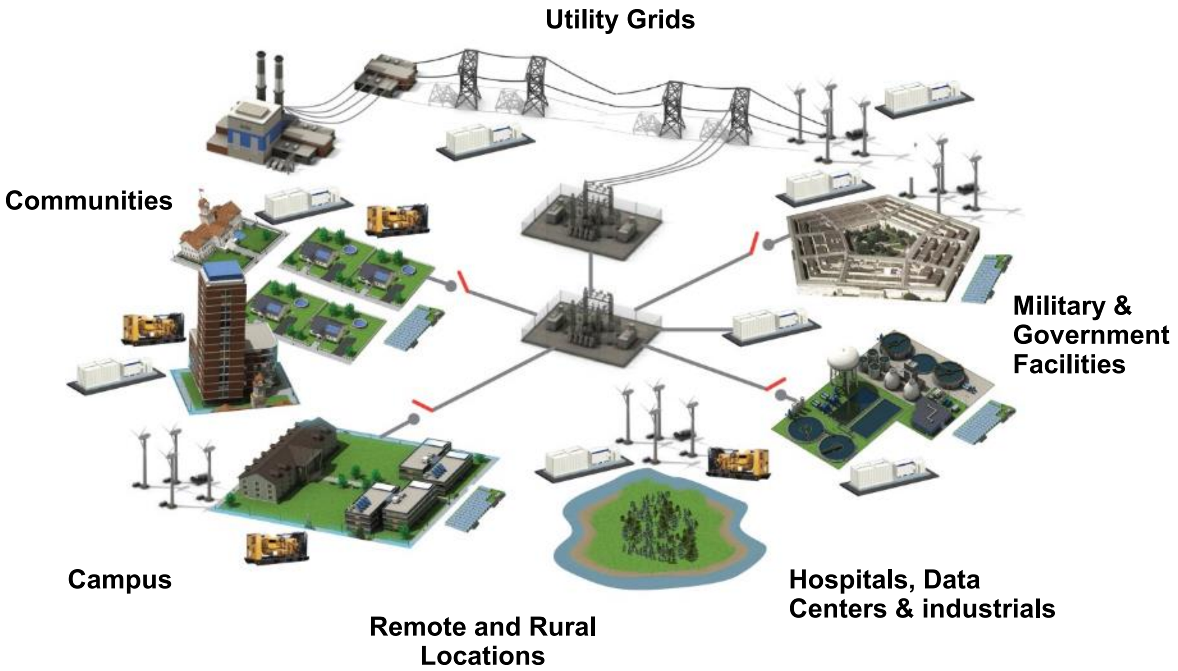
What is a microgrid



A group of generating assets and loads that can operate connected or disconnected from the utility grid

Distributed Energy Resources

- Traditional generators
- Natural gas generators
- Combined Heat and Power (CHP)
- Solar
- Wind
- Fuel cells
- Energy storage (batteries, other)

Local "Grid Within a Grid"

- Resiliency, reliability and uptime
- Revenue from participation in energy markets

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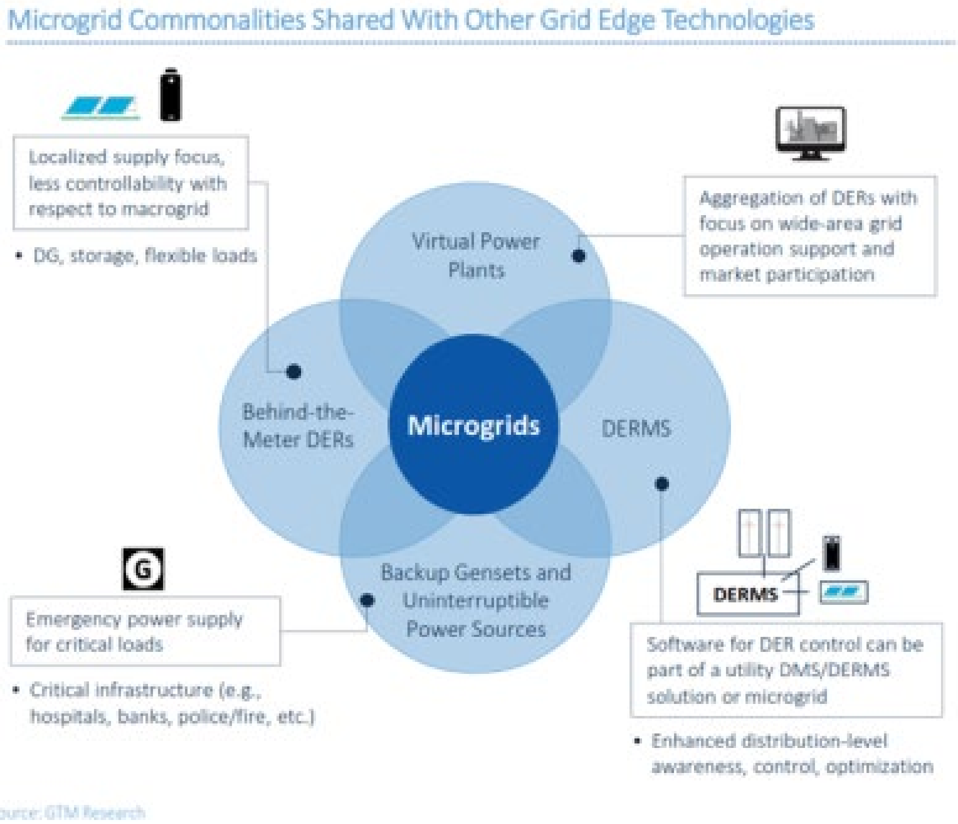
Microgrids intersect with other smart grid technologies

Microgrid technologies include:

- Switching and Distribution Equipment
- Protection Equipment
- Power Conversion Equipment
- Microgrid Control System
- High-Speed Communication Networks
- DER Analytics, DERMS
- Energy Management Systems at the Building, Community and Microgrid Levels (μEMS)



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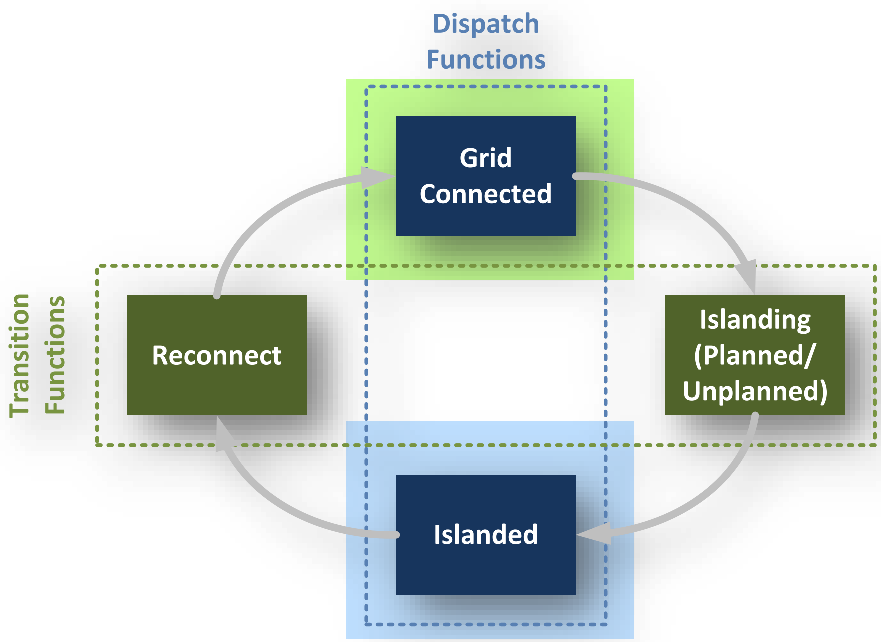
Microgrid control adds value and optimizes performance



Reduce Cost
- Manage Peak Demand / TOU
- Optimize Renewables
- Utilize Lowest-Cost Sources
- Minimize PF Penalty

Generate Revenue
- Demand Response
- Volt/Var Management
- Energy Arbitrage
- Frequency Regulation

Improve Power Quality
- Renewable firming
- Disturbance Ride Through

Optimize
- Minimize Fuel Cost
- Minimize Emissions
- Maximize Renewables

Stabilize
- PV Curtailment & Ramp Rate control
- Prioritize & Balance Sources, Loads

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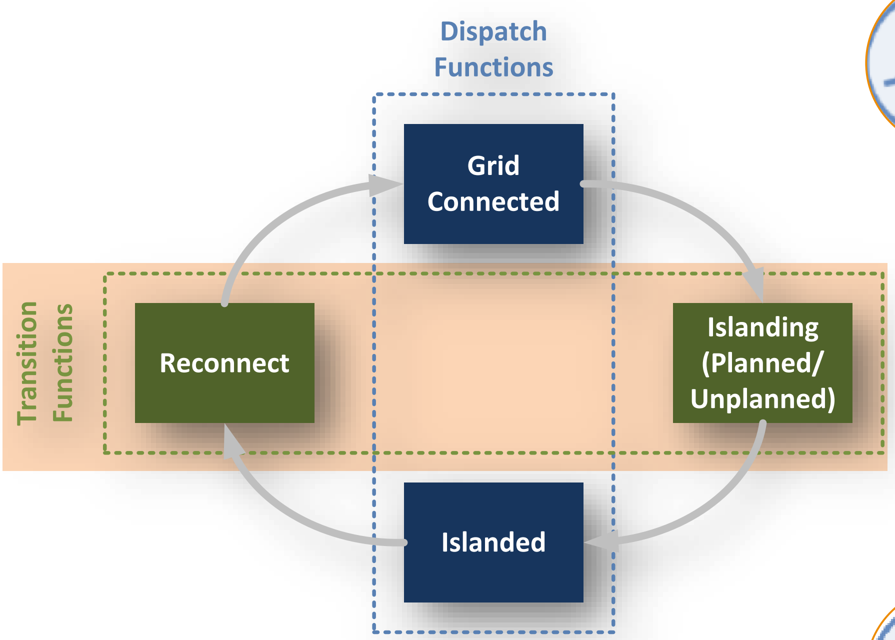
Microgrid control manages state transitions for resiliency



Planned Islanding
- Controlled / managed transition to minimize risk

Unplanned Islanding
- Speed / latency considerations
- Selection of DER equipment is key
- Stability analysis / load shedding is critical

Black Start
- Intelligent source selection
- Load restoration

Reconnection to Grid
- Control DERs to synchronize voltage and current

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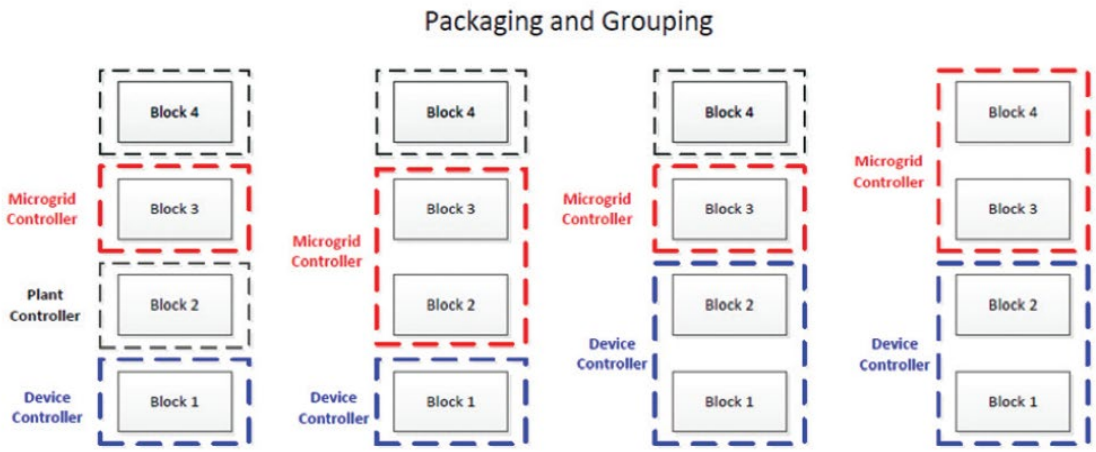
Control functions distributed in layers and devices



From *IEEE P2030.7* ***Standard for the Specification of Microgrid Controllers***

Block 4 – Grid Interactive Control Functions

- Area EPS Control
- DMS
- SCADA

Block 3 – Supervisory Control Functions

- Forecasting
- Data management & Visualization
- Optimization (Volt/VAR, Economic Dispatch)
- Dispatch

Block 2 - Local Area Control Functions

- Sequencing / Status Control
- Load Management
- Fast Transition – management
- Resynchronization
- Disturbance Recording

Block 1 – Device Level Control Functions

- Voltage / Frequency control
- Reactive Power Control
- Load Control
- Energy Storage Control
- Generator Control
- Fault Protection & Island Detection

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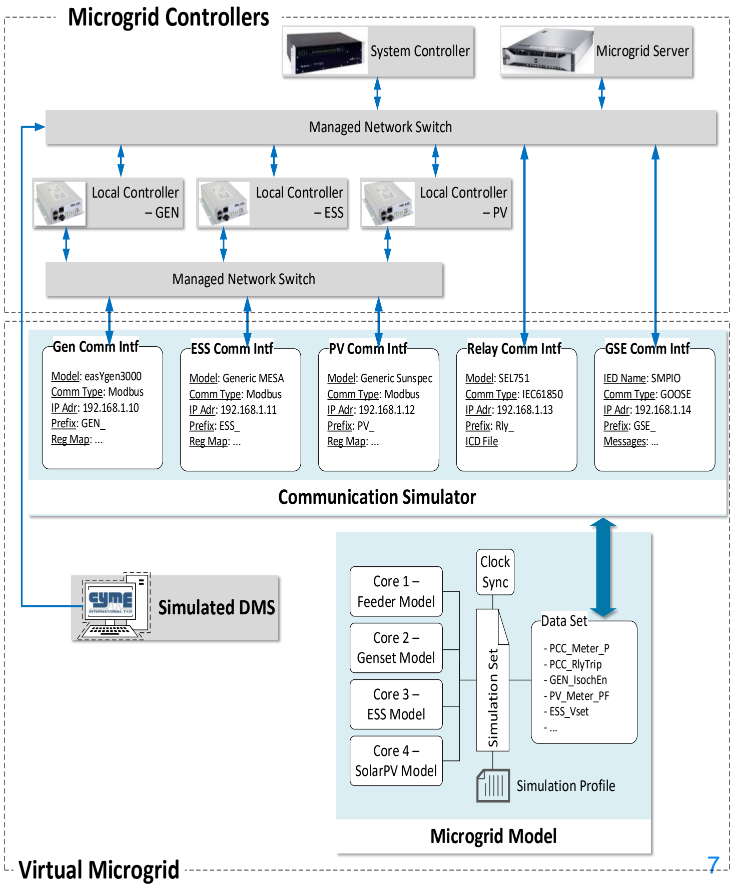
Testing of complex integrated control reduces risk

Virtual microgrid hardware-in-the-loop modeling & testing

- A “Digital Twin” to validate and optimize system performance BEFORE construction
  - **Reduce risk**
  - **Reduce start-up cost**

- Increased understanding of the system dynamics and feasibility based on data from simulation
- Imported site data used to develop system load profile and utility rate structures
- Exported data used to measure and evaluate performance metrics prior breaking ground



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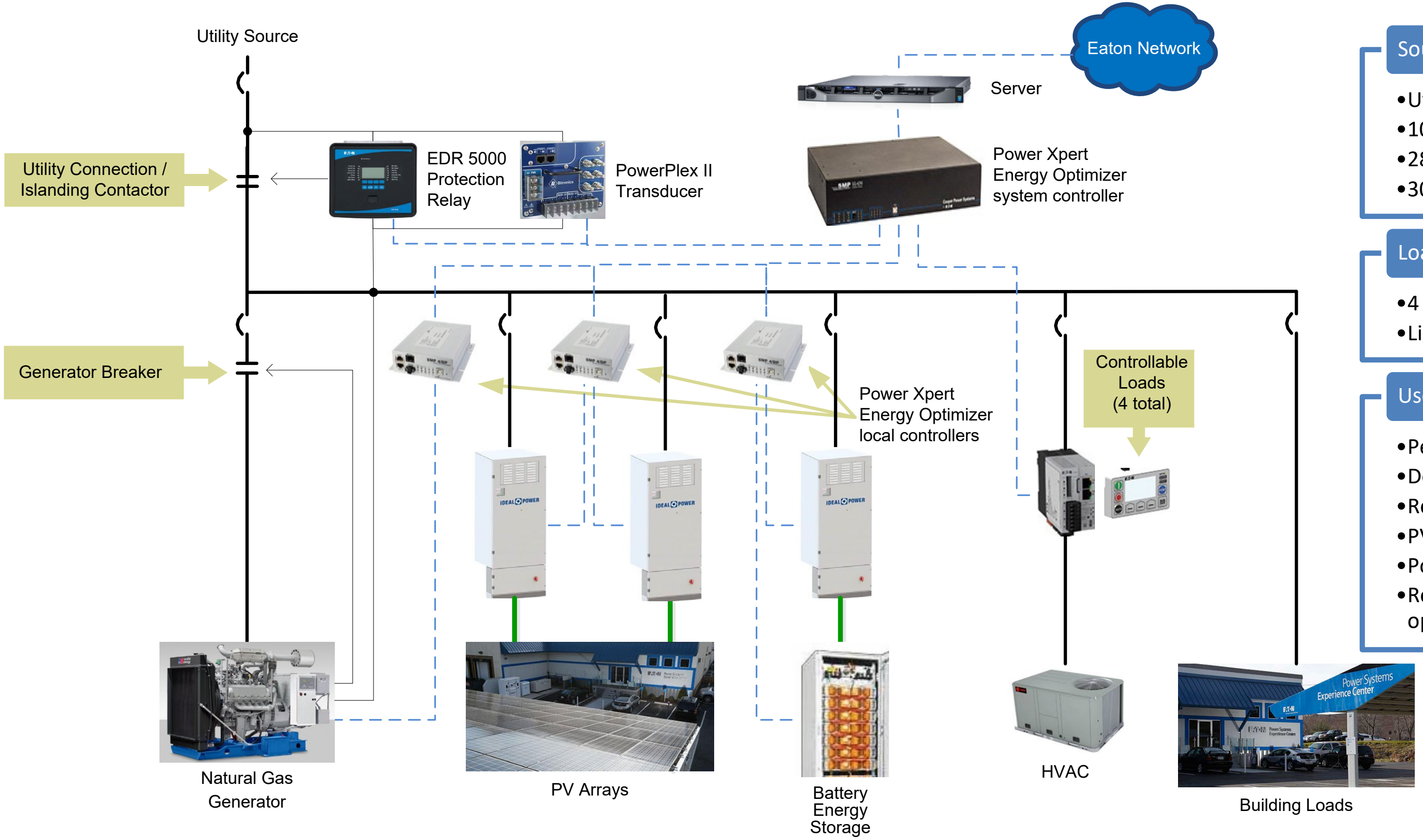

Sources

- Utility
- 100 kW Generator
- 28 kW Photovoltaic
- 30 kW Battery Storage (30 kWh)

Loads

- 4 Controllable HVAC units (4 -25 kW)
- Lights, outlets, etc. (8-12 kW)

Use Cases (partial list)

- Peak Power Limiting / Load Leveling
- Demand Management
- Renewable Firming
- PV Shifting
- Power Factor Control
- Resiliency: Islanded operation optimizing renewables

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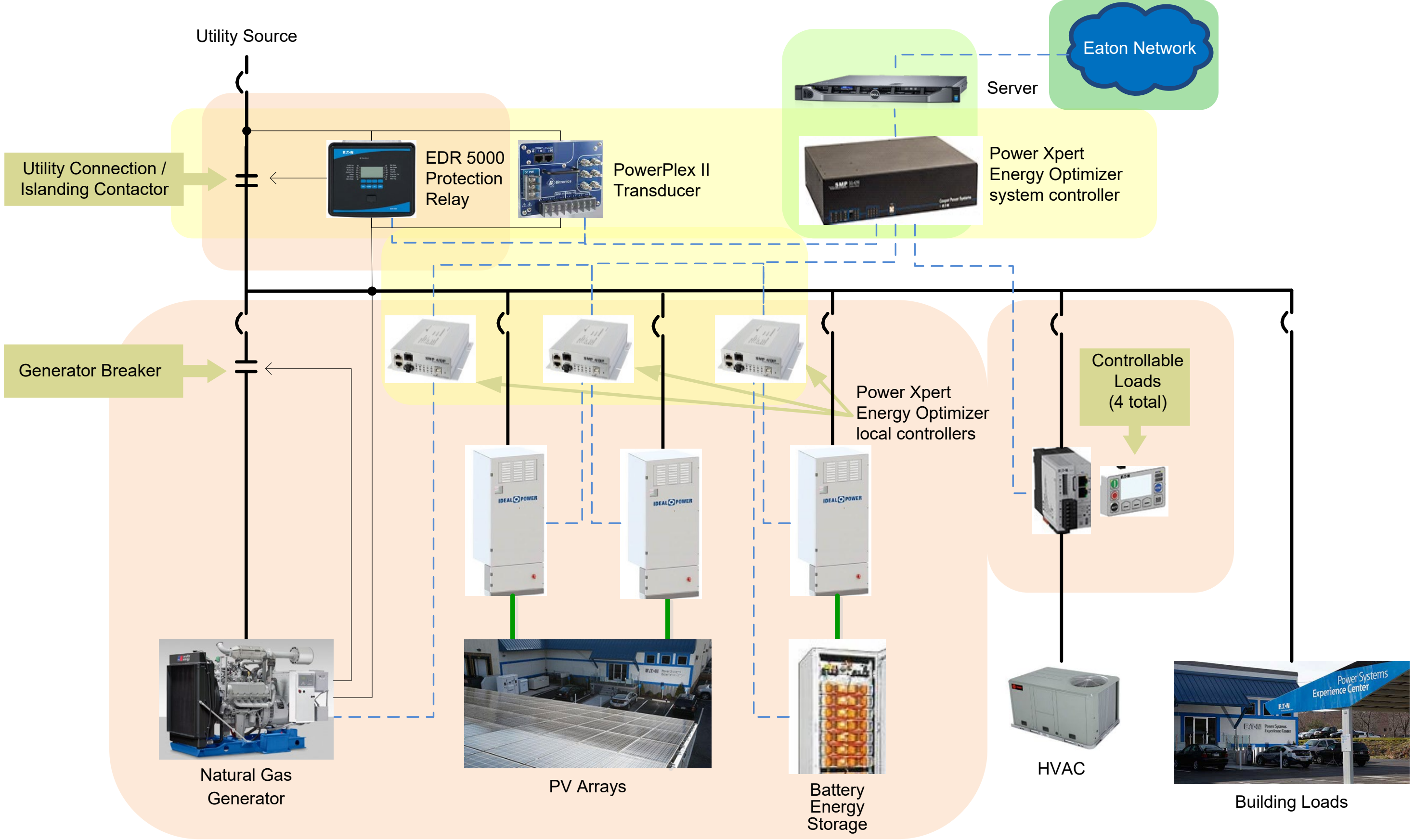

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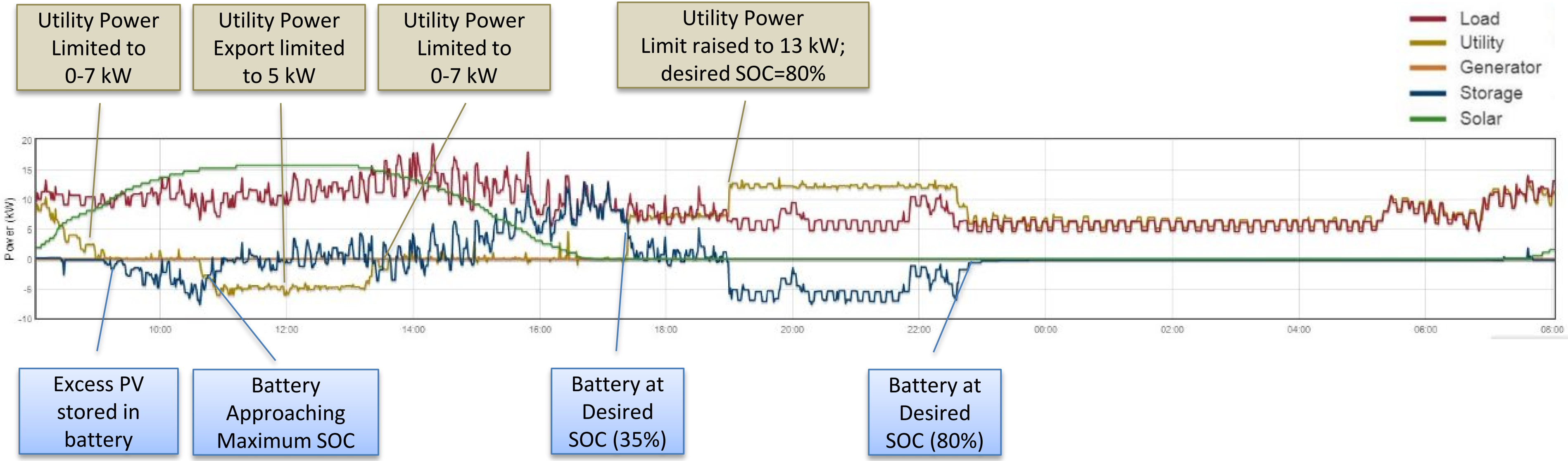
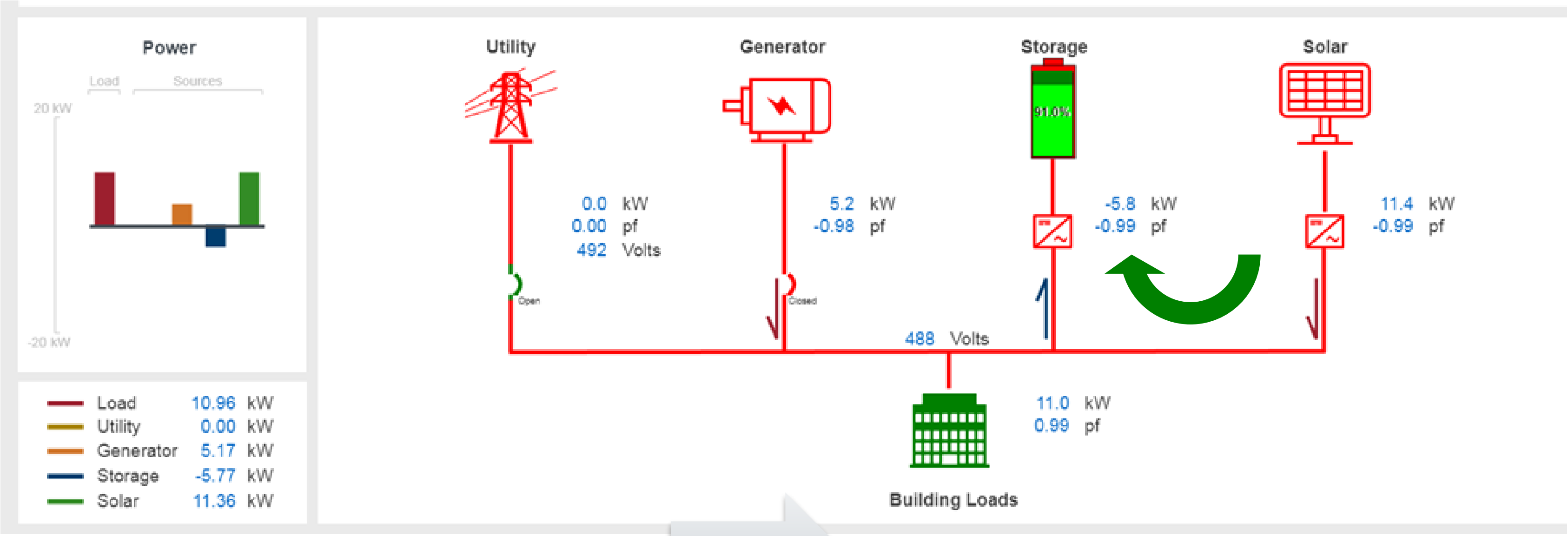
Actual Microgrid Performance - 24 hour period

Conditions:
- Winter Loading
- Sunny

Functions Illustrated:
- Power Limiting – On Grid
- Scheduled Operation



Islanded operation requires coordinated control of sources



Challenge

- Load on generator must remain above a minimum level
- PV output varies and may exceed load

Solution

- Store excess energy from PV

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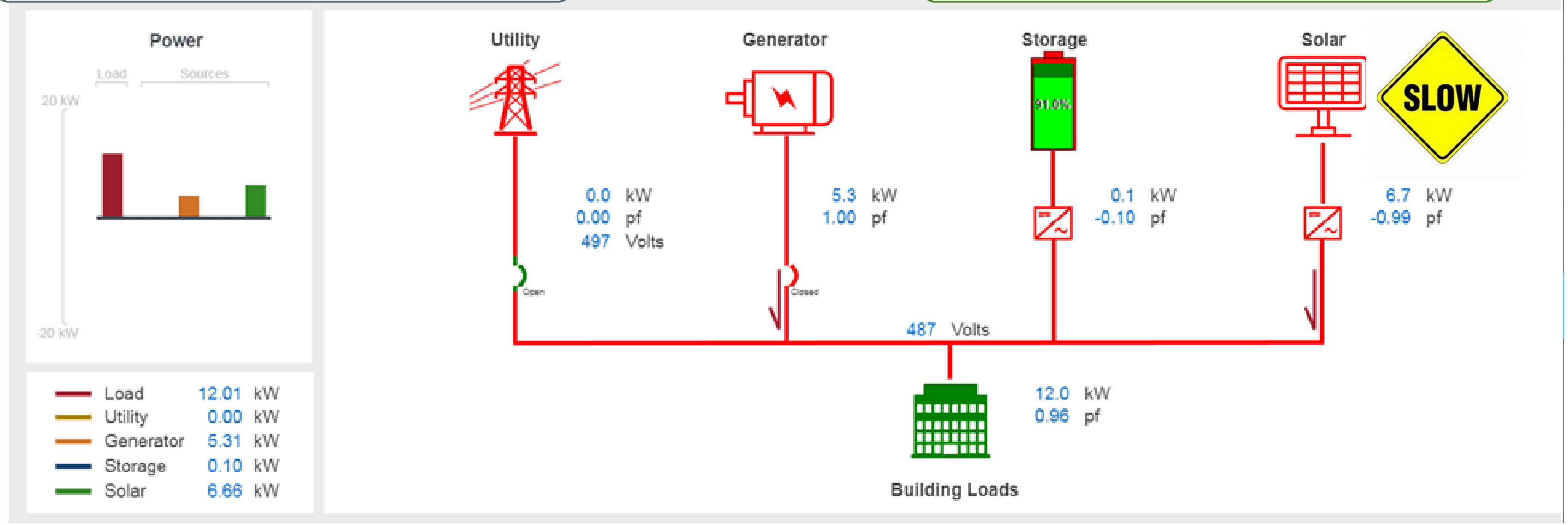
Islanded operation requires coordinated control of sources

Challenge

- Load on generator must remain above a minimum level
- PV output varies and may exceed load
- **Energy storage is “full” or offline**

Solution

- Actively curtail PV output
  (requires fast curtailment capability in inverter)



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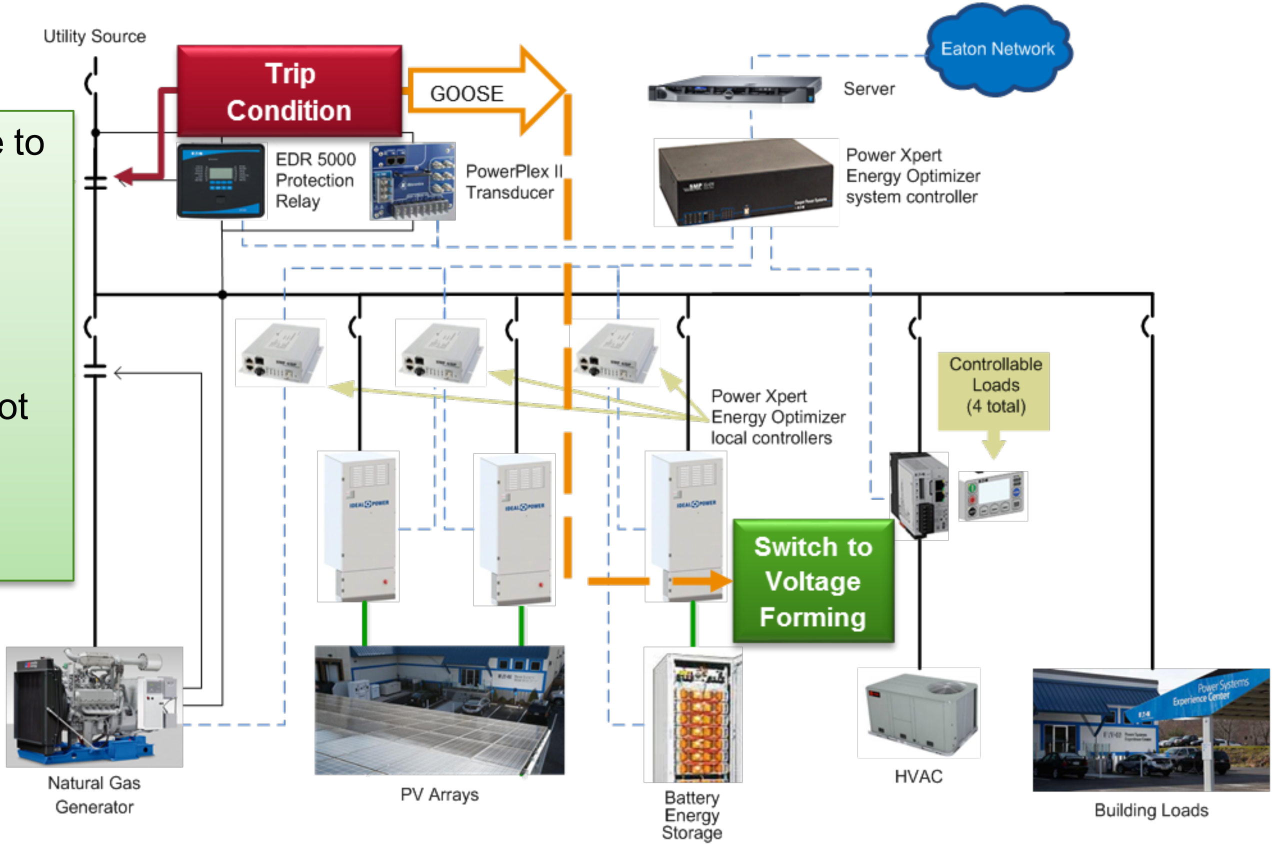
Islanding presents integration challenges

- “Seamless” islanding in response to grid disturbances is <u>not</u> trivial
- Overlaying a “control” doesn’t overcome device-level control deficiencies
- “High speed” communication is not instantaneous

  Actual measurements: 8-10 msec. latency utilizing GOOSE



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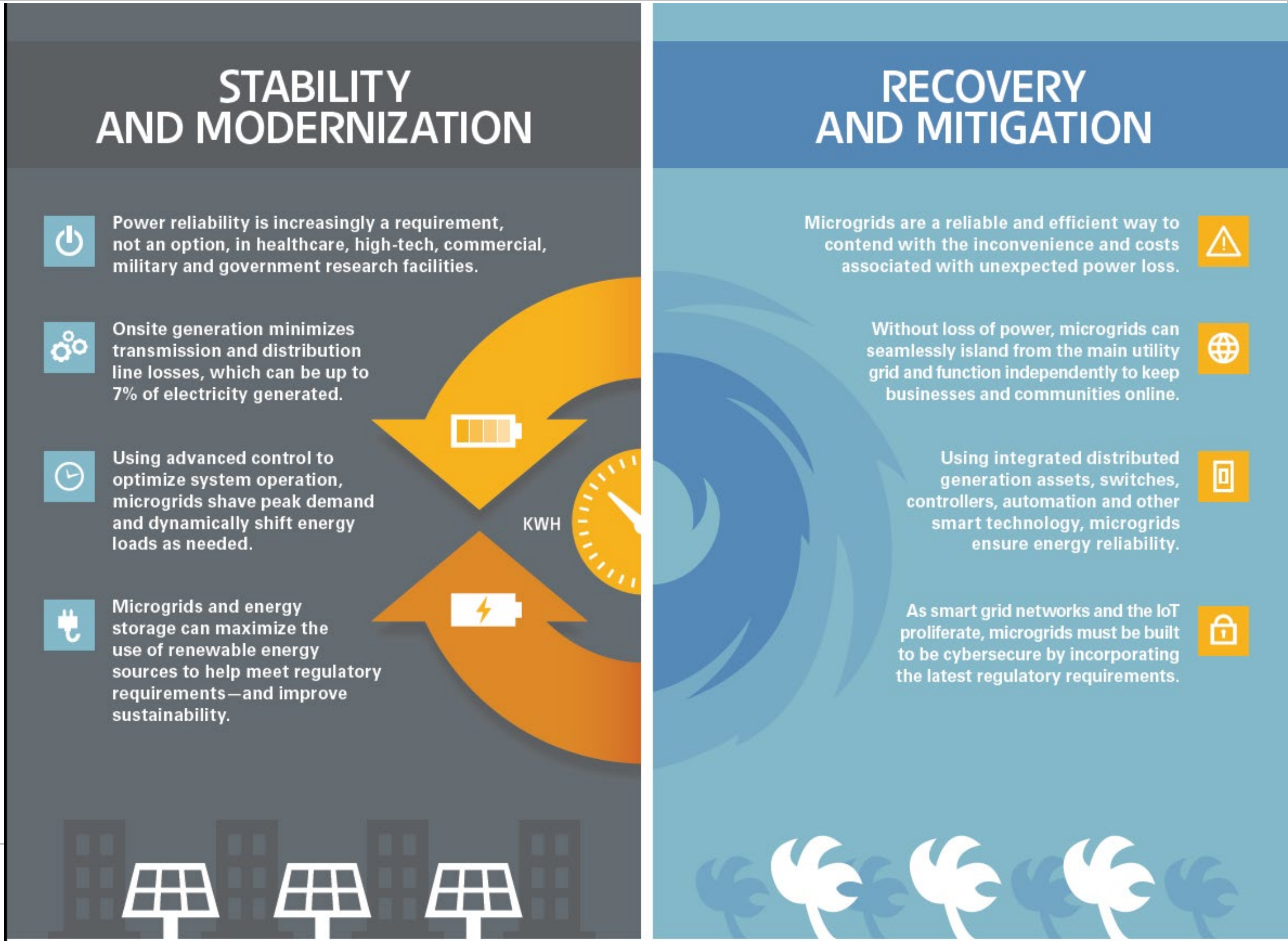
MICROGRID ENERGY SYSTEMS

for protection and peace of mind

Microgrids are stand-alone power generation, distribution and storage systems that work with or independently from the main utility grid to help business, campuses and communities better respond to fluctuating power demands and avoid power disruptions.



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