



Microgrids and Integration of Clean Energy

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Powering Business Worldwide

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Microgrid – Definitions

“A microgrid is any portion of the larger utility grid that can be intentionally isolated/islanded from the larger grid and continue supplying customer loads.”

- *Panel discussion, 2011 IEEE ISGT Conference*

“A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode.”

- *Microgrid Exchange Group, October 2010*

“The fundamental concept of a ‘microgrid’ can be summed up this way: an integrated energy system consisting of distributed energy resources and multiple electrical loads operating as a single, autonomous grid either in parallel to or ‘islanded’ from the existing utility power grid.”

- *Pike Research*

Key Elements of a Microgrid

Must Have

- Electrical Sources
 - *(*)Capable of island operation and/or parallel with grid*
 - Sources > Loads*
- Electrical Loads
 - Loads < Sources OR intelligence & load control*
- Defined PCC
- Isolating means*
- Intelligence / integrated purpose

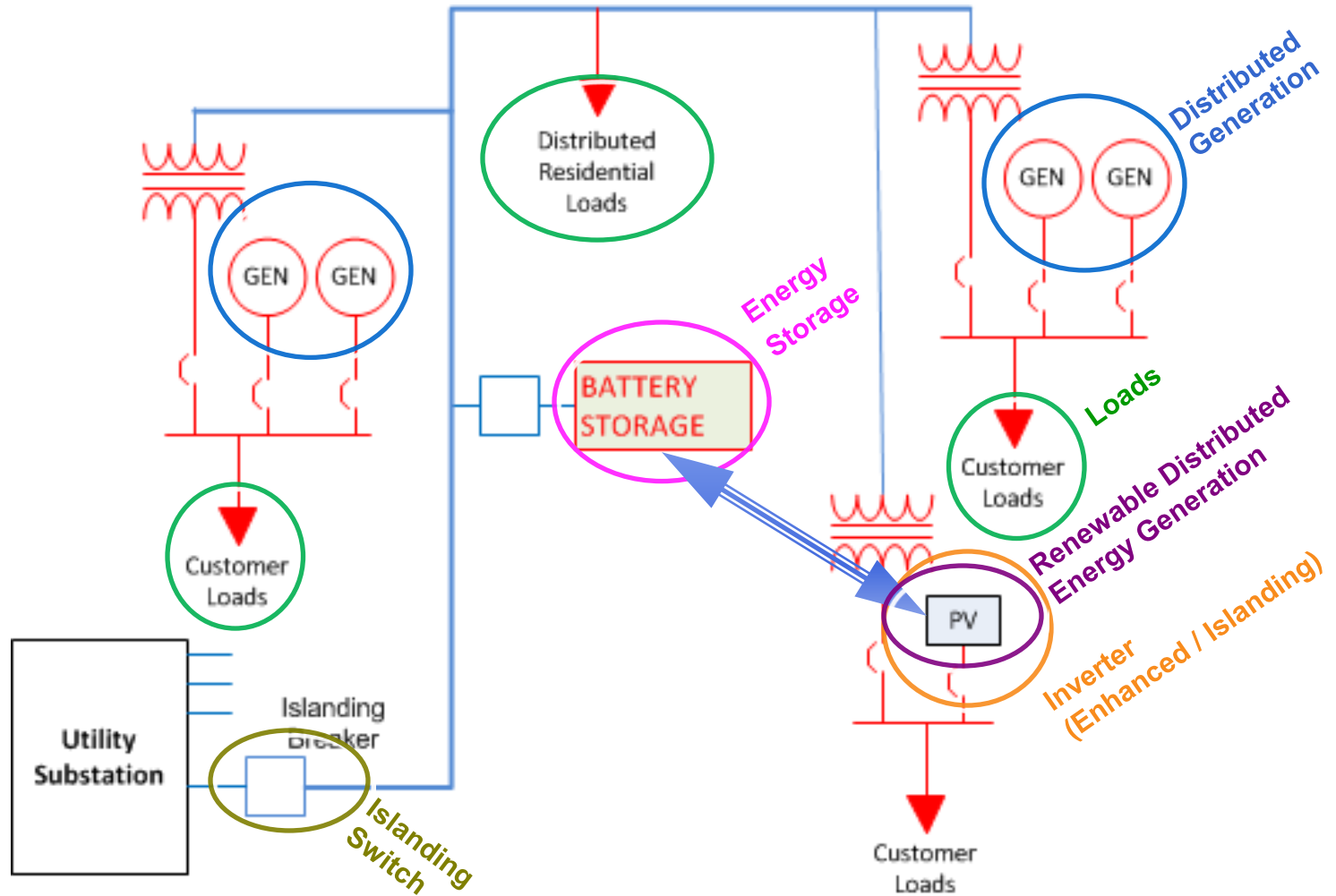
May Have

- Heat Sources & Heat Loads
- Energy Storage

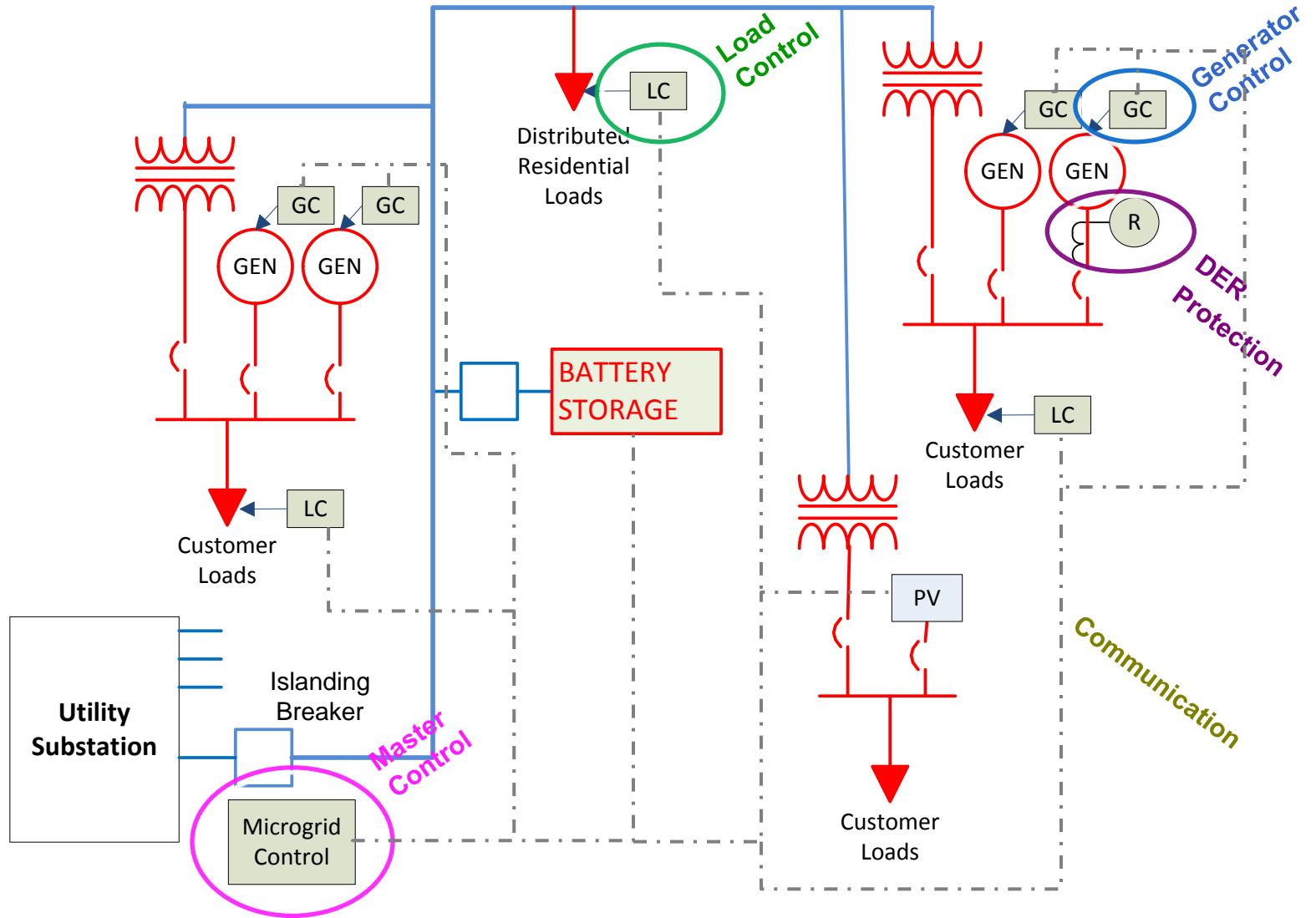
Other Criteria

- Continuous duty (not an emergency power system)
- < 10 MW (?)
- Operated for the benefit of the customer and/or utility

Key Elements of a Microgrid



Key Elements of a Microgrid



Architecture

Community/Utility

- Urban or rural communities
- Connected to utility grid
- Utility distribution incorporated into microgrid
- Variety of DER over large area
- Relieve demand in dense load areas
- Reduce blackout duration (operate in Island mode)
- Encourage use of Renewable Generation
- Defer Utility infrastructure costs

Commercial/Industrial, Institutional/Campus, Military (Grid-Tied)

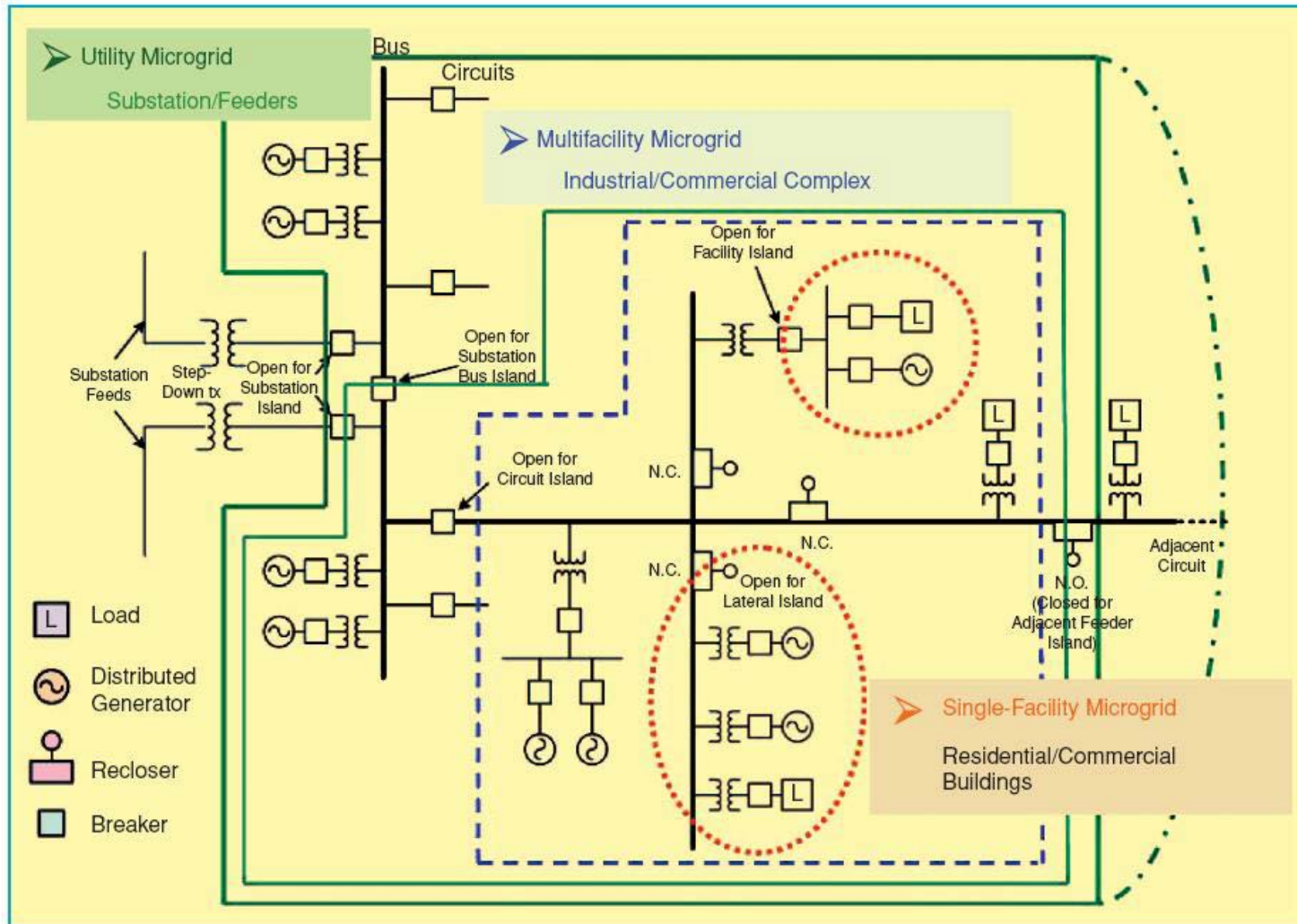
- High level of power quality and reliability
- Single facility or multi-facility site such as a shopping center or university campus.
- Relatively compact (geographically)
- Real-time power generation controls that can take advantage of price signals
- Demand-side management
- Reduce blackout duration (operate in Island mode)

Remote Off-Grid, including Military Off-Grid

- Stand-alone facility, campus, or community
- Typically geographically isolated
- May be temporary / portable
- Source and load control coordination essential
- Storage can be key

Source: Pike Research

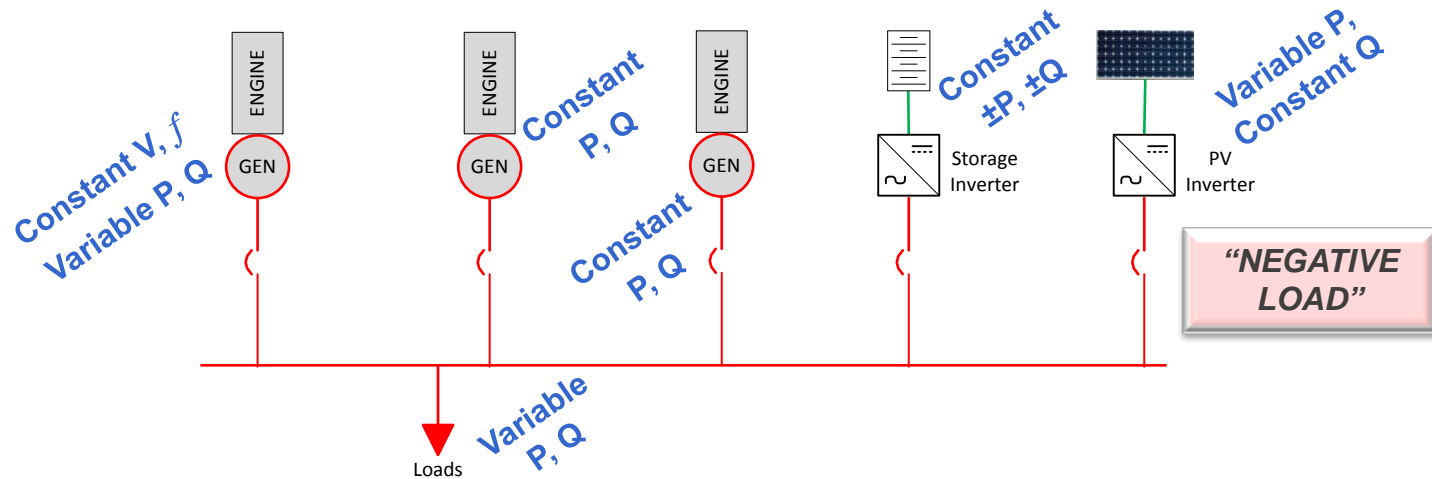
Architecture



Source: IEEE

Source & Load Control

Islanded – Isoch + Base Load



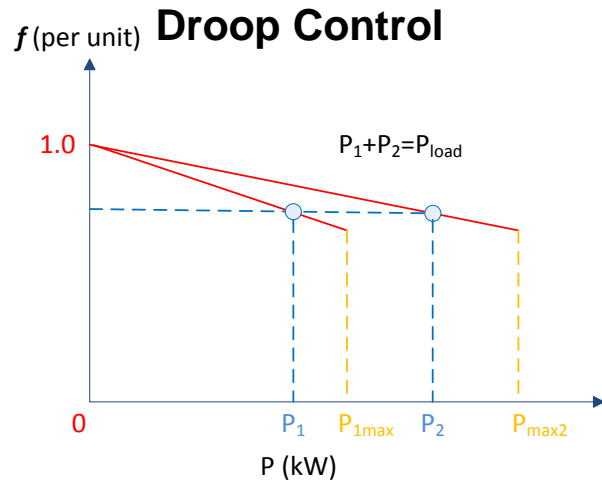
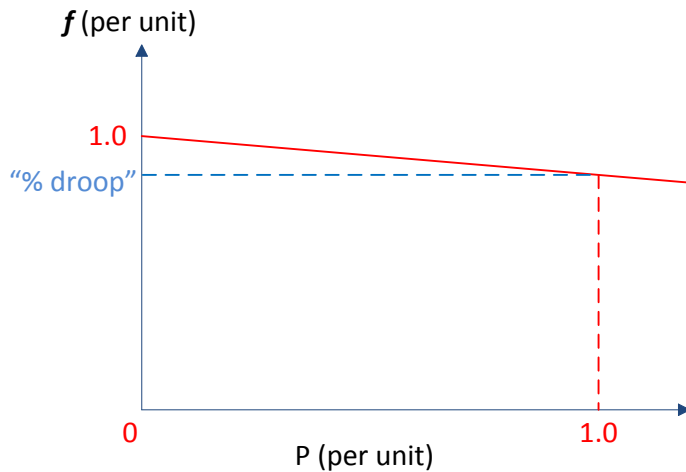
Advantages:

- Dispatch P, Q at “slow” speed
- Unsophisticated / slow communication is adequate
- Base Load Unit efficiency optimized

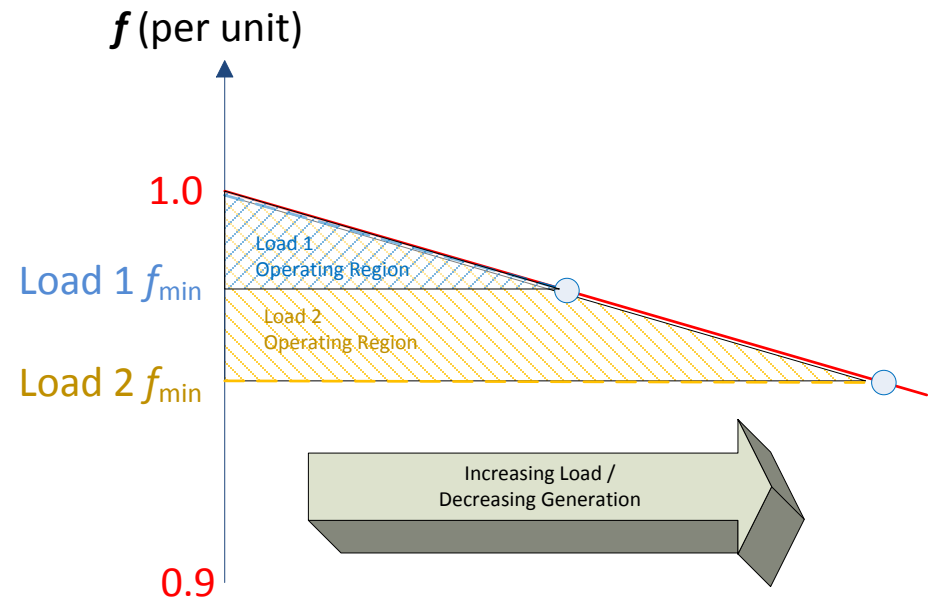
Disadvantages

- Base Loading complex for CHP
- Isoch unit > short-term load (and PV & Wind) variability
- Requires communication and overall control(not autonomous)

Source & Load Control



Droop Control – 2 unmatched sources



Droop Control – Applied to Loads

Control Architecture

Autonomous

- Simplified installation
- Does not rely on communications
 - No / limited cyber security concerns
 - Lower cost
- Likely relies on droop control, passive synchronization
- Cannot maximize economic dispatch
- Individual sources, protection, etc. is “unaware” of system status (generators, islanded or not, etc.)

Master Control

- Allows efficient dispatch
- Flexible control
- Points in system are aware of status – switch protection settings, etc.
- Allow reclosing only under certain conditions
- More complex and expensive
- Increased vulnerability

Summary - Opportunities / Obstacles

Potential Benefits

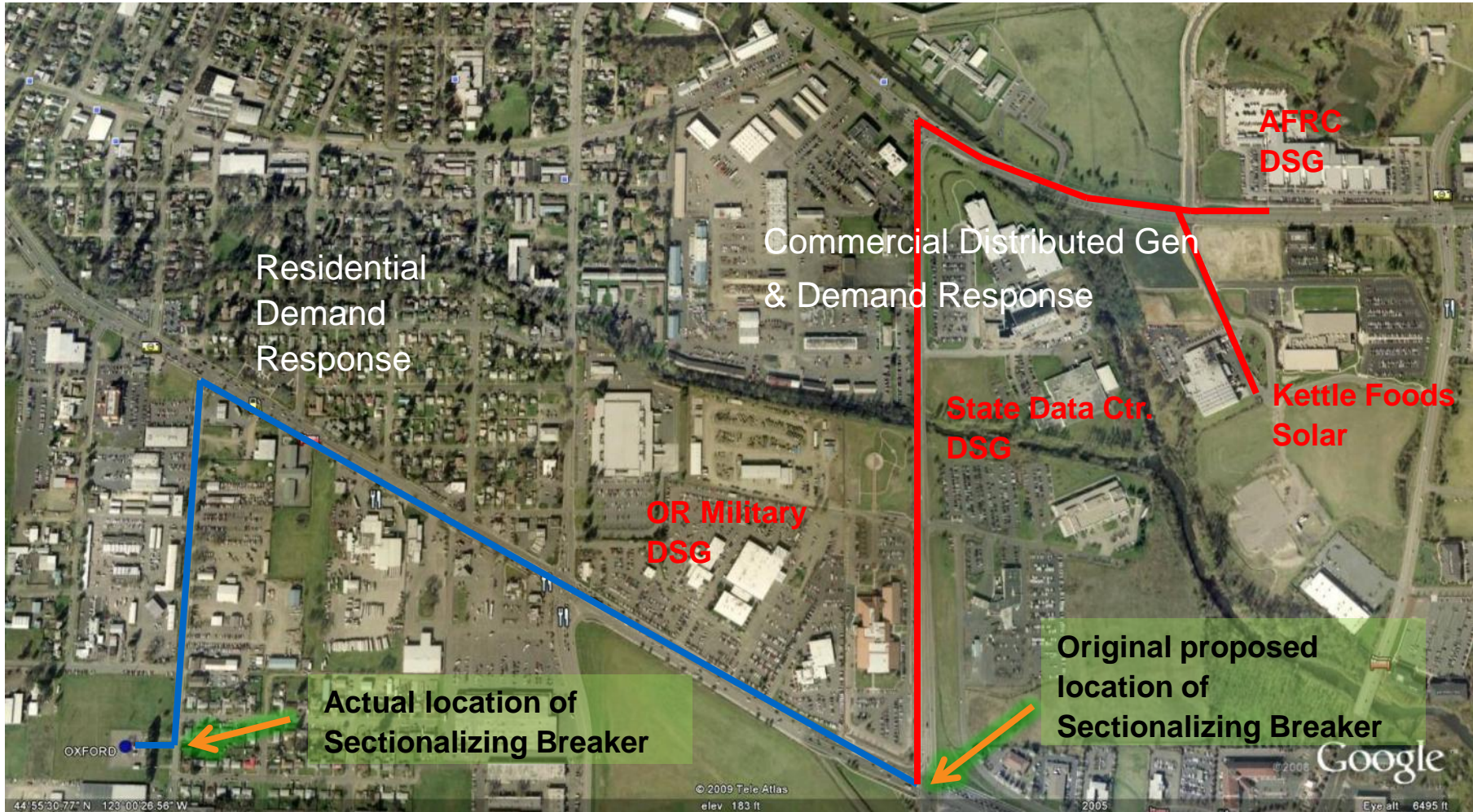
- Modular - Install generation rapidly to meet load growth
- Capital / Infrastructure deferment
- Address renewables (wind, solar)
- Increased energy efficiency / Reduced losses
- Increased reliability
- Enhanced power quality
- Local energy visibility / Consumer awareness
- Microgrid becomes “active distribution system”

Potential Obstacles

- Standards development and acceptance
- Policies, Regulatory Environment
- Engineering & design costs / lack of “Plug & Play”
- Equipment costs
- Equipment / technology availability
- Security

Microgrid Example

Utility Feeder Microgrid

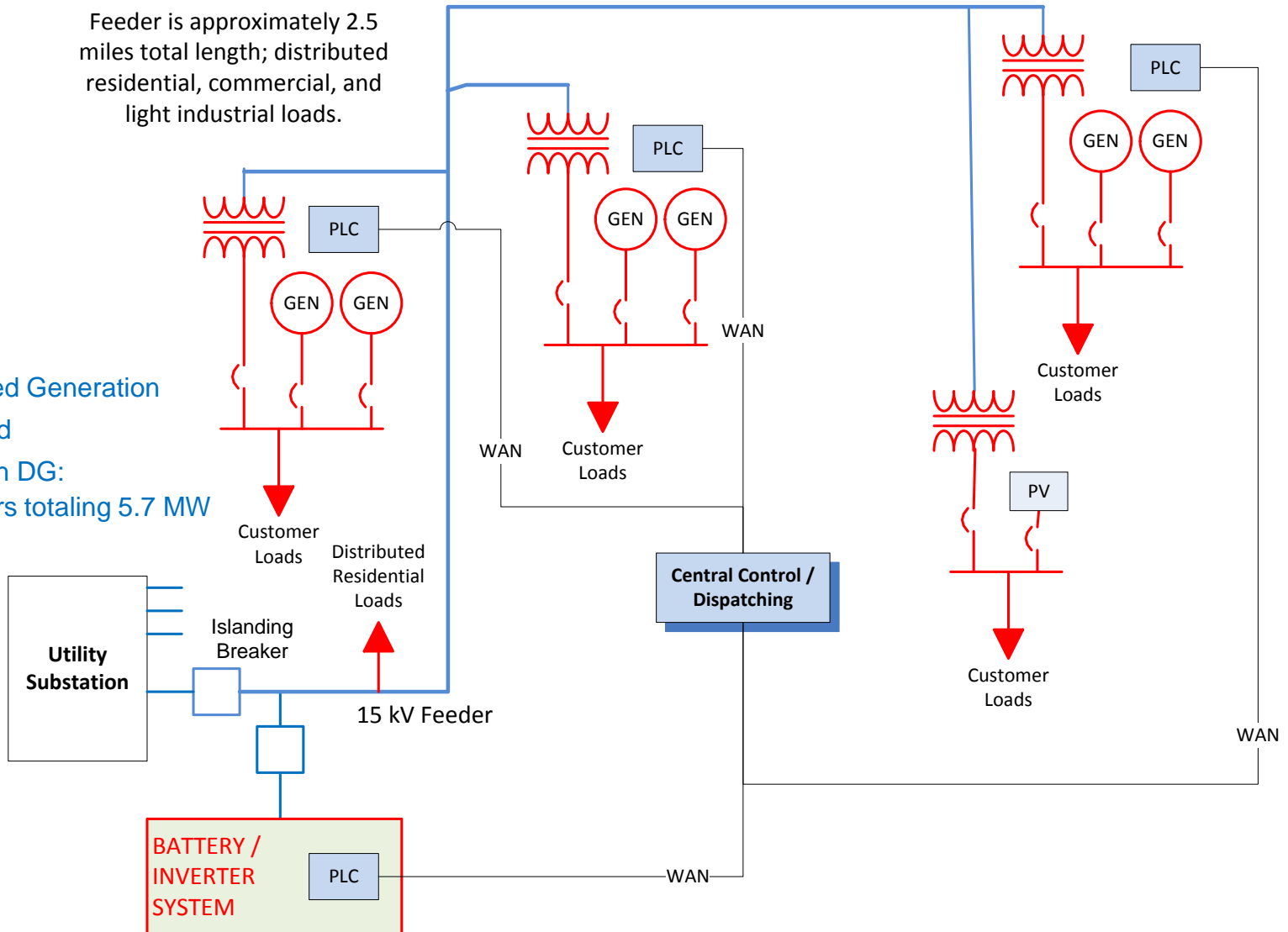


Utility Feeder Microgrid

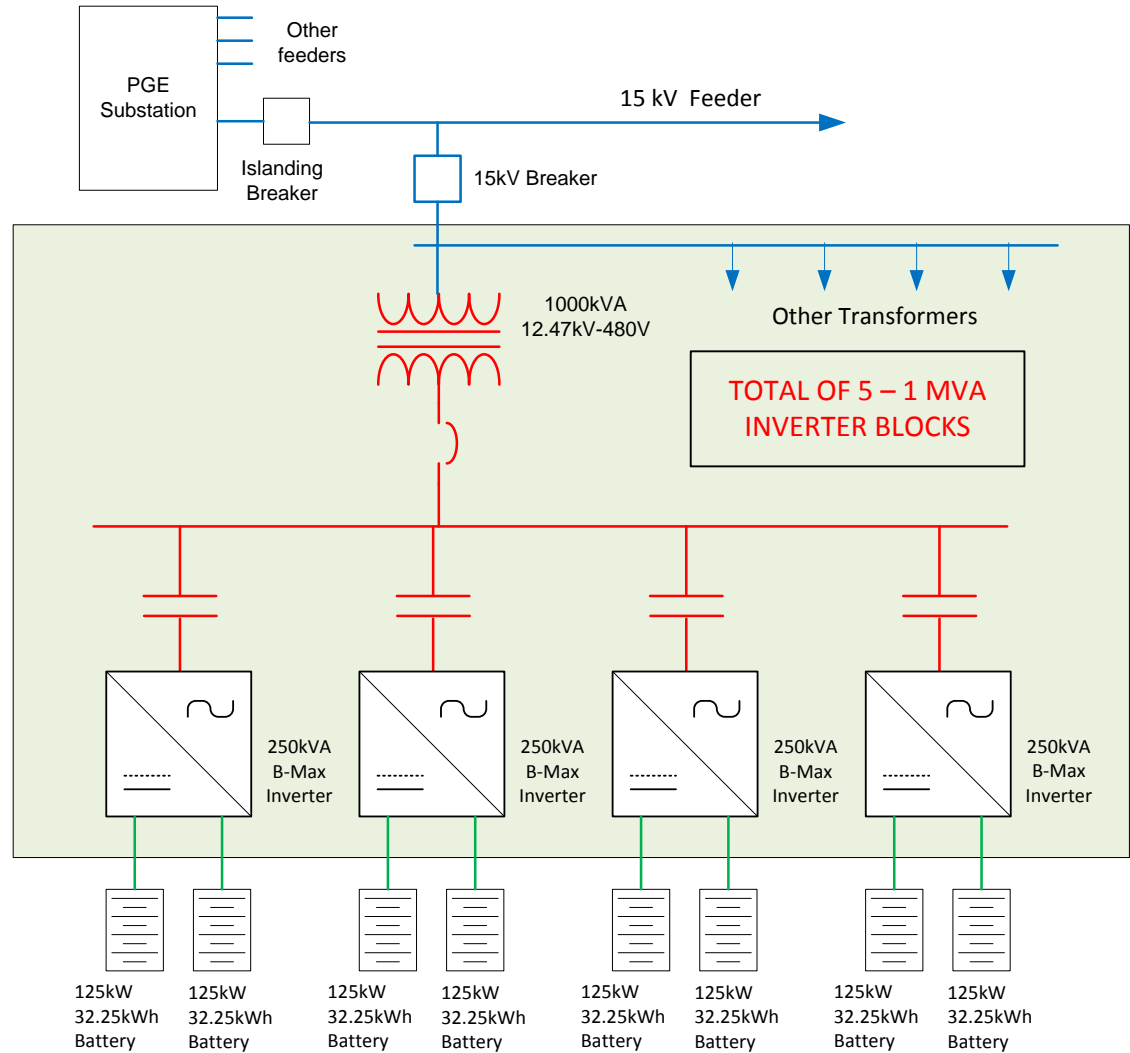
Feeder is approximately 2.5 miles total length; distributed residential, commercial, and light industrial loads.

EXISTING Distributed Generation

- Utility dispatched
- 3 customers with DG:
6 total generators totaling 5.7 MW



Utility Feeder Microgrid



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