Microgrids

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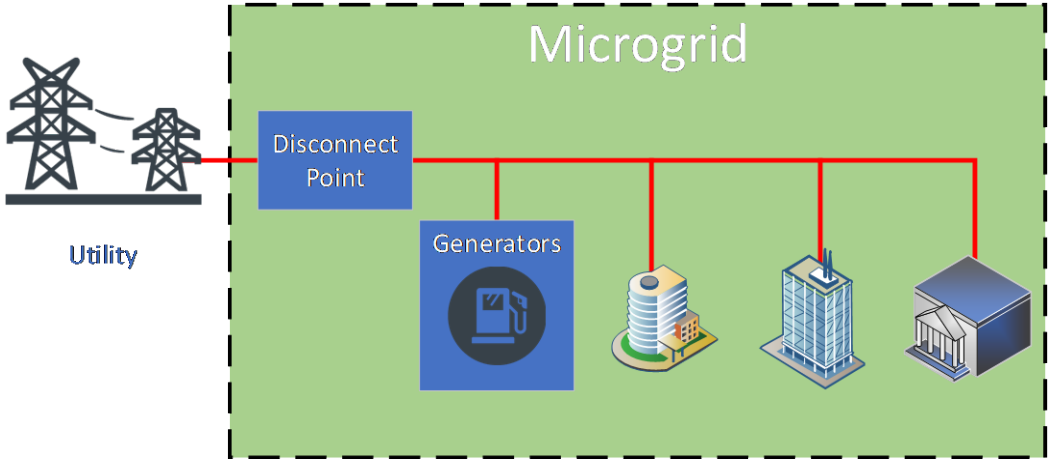
What is a Microgrid?

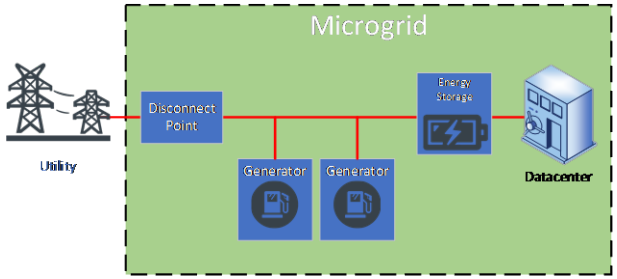
Microgrid Definition

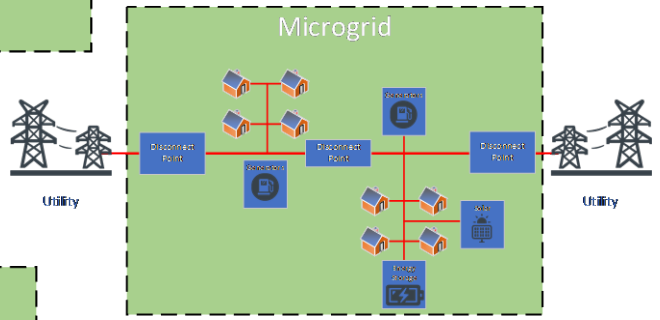
- **Definition:**
  - A group of interconnected loads and resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid.
  - A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or islandmode.
  - A microgrid can also operate always isolated from the grid (remote locations).

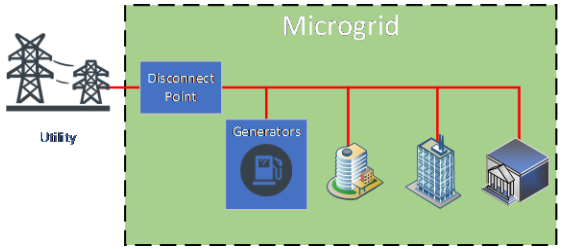


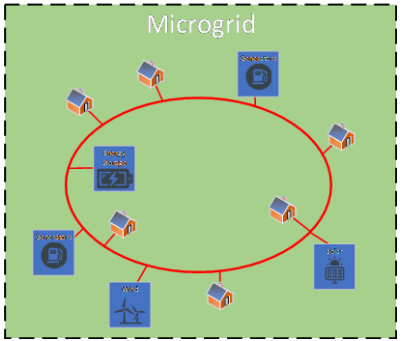
Microgrid Applications

- **Commercial/Industrial:**
  - Built for reducing costs during grid-tied and providing backup powers:
- **Community/City/Utility:**
  - Improve reliability, emission and energy targets.
- **Facility:**
  - Link together critical facilities and combines new/existing equipment.
- **Rural Communities (Islands/AK):**
  - Sometimes grid-connected, offset fuel and increase resiliency.







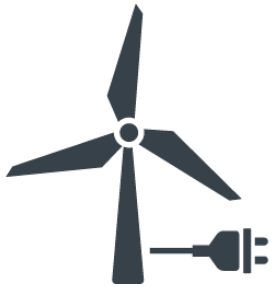


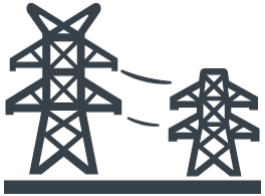
Microgrid Benefits

- **Reliability:**
  - Backup system for grid
  - Diversity of fuel sources
- **Economic:**
  - Grid-tied services (ancillary services)
  - Renewable production
  - Energy Efficiency
- **Other:**
  - Improved power quality
  - CHP integration
  - Electrification

Microgrid Challenges

- **Renewables:**
  - Reduces fuel usage
  - Highly variable
  - Requires backup source
- **Stability/Control:**
  - Weak grid
  - Grid interaction + islanded modes
  - Grid protection
- **Value of Resiliency:**
  - How to quantify benefit of 99.9%
- **Regulatory:**
  - High renewable percentage
  - Outside connections
  - Synchronization





How is a Microgrid Designed?

Microgrid Analysis

Inputs:

Mission goals

Utility cost structure

Historic/projected load data

Location & RE potential

Analysis:

Techno-economic

Load served

Possible solutions

Outcomes:

Components and sizing

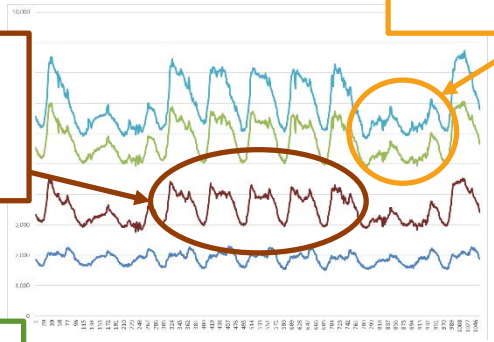
Operational Modes

Analysis

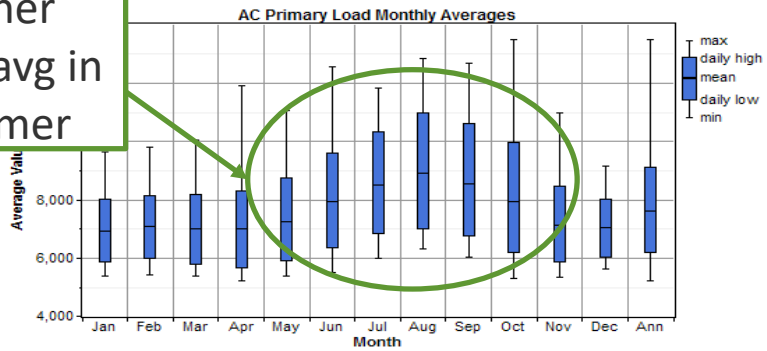
- **Load / Renewable Data:**
  - Daily profile
  - Yearly profile

Lower peaks on weekend

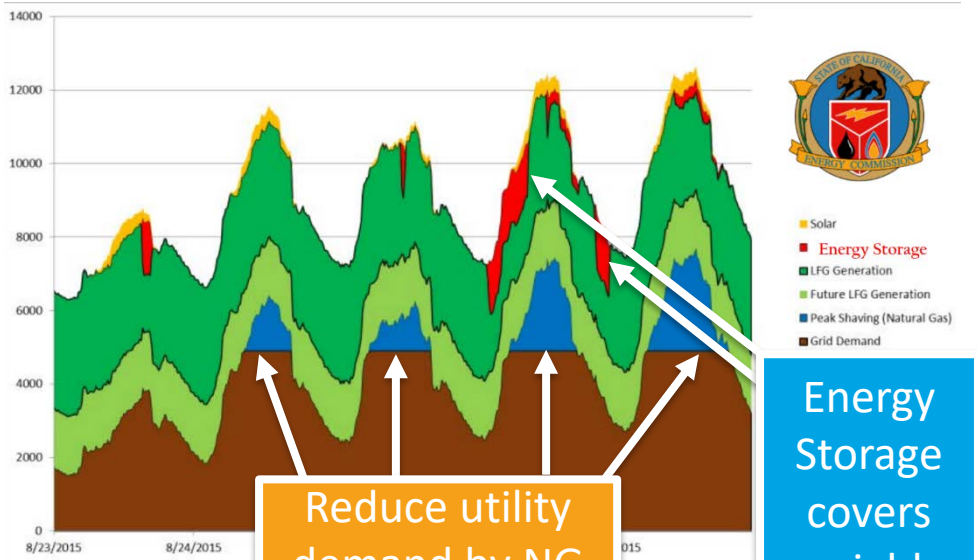
Higher peaks on weekdays



Higher peak/avg in summer



- **Techno-Economics:**
  - Demand management
  - Component sizing

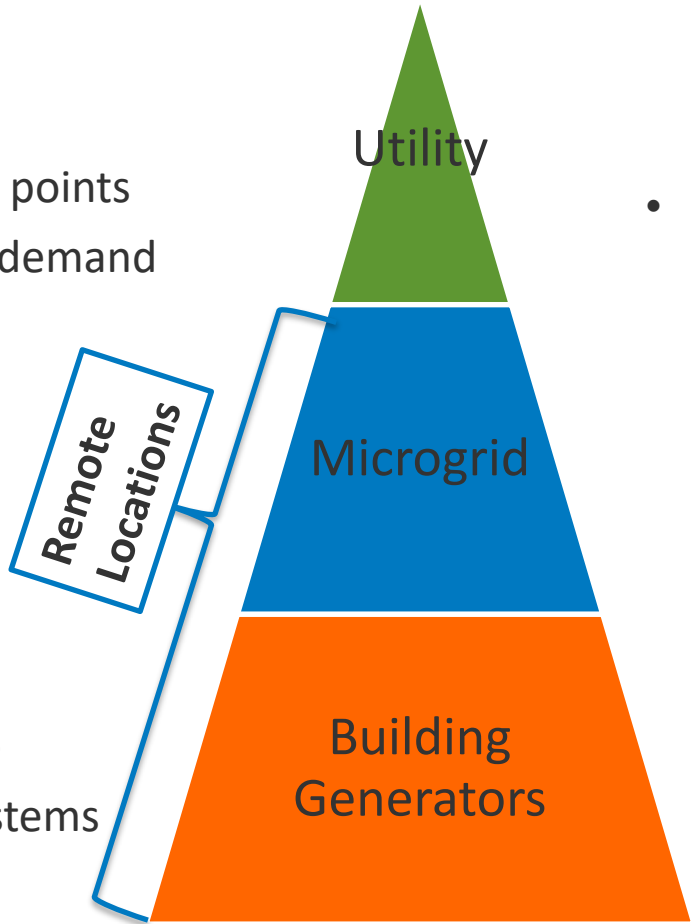


Reduce utility demand by NG generators

Energy Storage covers variable RE

Layers of Resilience

- **Utility:**
  - SAIFI, SAIDI rates
  - Multiple connection points
  - Renewables reduce demand



- **Microgrid:**
  - Backup for utility
  - Short outages possible
  - Fuel delivery / availability
  - N+1, N+2
  - Support full load?
  - Renewables extend operation during outages with a limited fuel supply

- **Building Generators:**
  - Last line of defense
  - Works with UPS systems

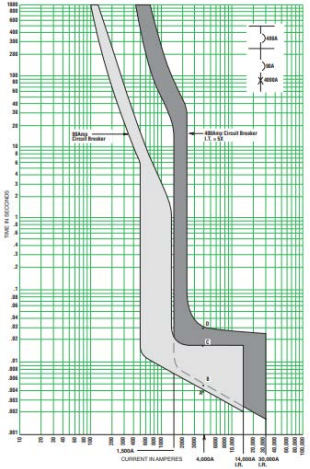
Engineering Considerations - Components

- **Sizing**
  - Generators
    - Number
    - Size (W)
    - Redundancy (N+1/N+2)
    - Emissions

  - Renewables
    - Concentrated or distributed
    - Size (W AC and DC)
    - Design life

  - Energy storage
    - Allows diesel off operation
    - Design life
  - Isolation devices
    - Sectionalize the grid
    - Backup path(s)

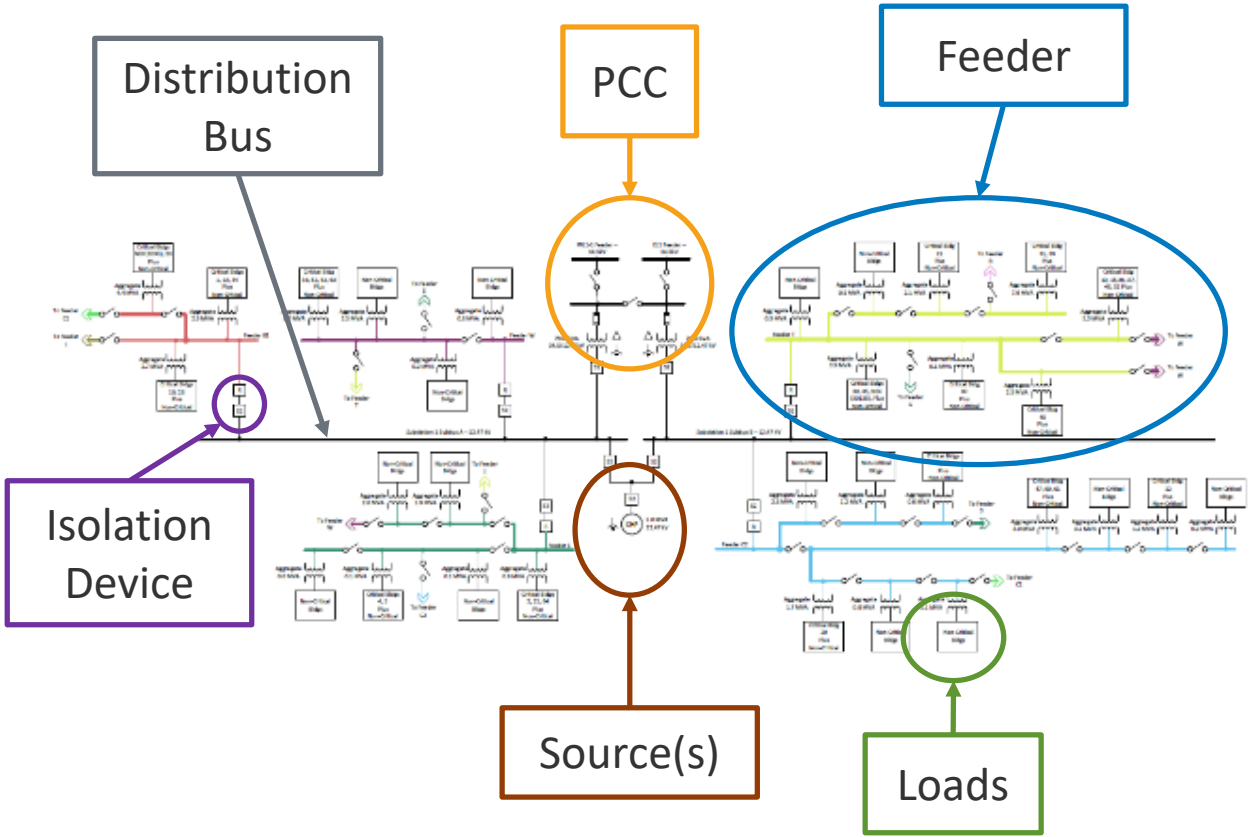
- **Protection:**
  - Grid vs. MG mode
  - Arc-flash study
  - Coordination, arc-flash and flow studies



- **Utility:**
  - Interconnection agreement
  - Minimum import
  - Rate structure

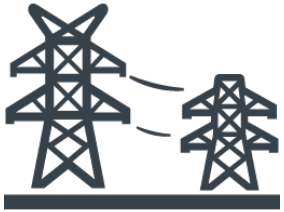
Engineering Considerations – One-Lines

- Source location(s)
  - Electrically
  - Physically
- Load locations
  - Electrically
- Point(s) of common coupling (PCC)
  - N/A to remote locations
- Distribution bus(s)
  - Breaker connections
  - Same voltage
- Transformers
  - Change voltage
  - Must be energized
- Isolation devices
  - At PCC
  - Feeder isolation



Microgrid Concepts

Operational Modes



Vs.

Remote locations only operate in this mode.

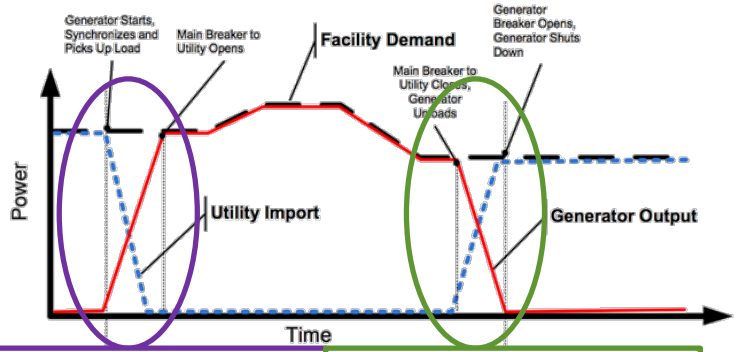
- **Grid-Tied Mode:**
  - Frequency is set by the grid
  - Microgrid sources can operate independently
  - Real and reactive power regulated at point of coupling
  - Voltage impacted locally by sources
  - Available fault current is high
  - Little impact from variable renewables and loads

- **Island Mode:**
  - Frequency set by grid-forming source
  - Sources will share load or output constant power
  - Sources will share reactive power
  - Voltage impacted locally by sources
  - Available fault current is low
  - Large impact from variable renewables and loads

Utility <-> Island Transitions

Closed Transition

- Planned sequence
- Generators sync and share with utility
- Timeframe varies 20 ms to 5 min
- No loss of power

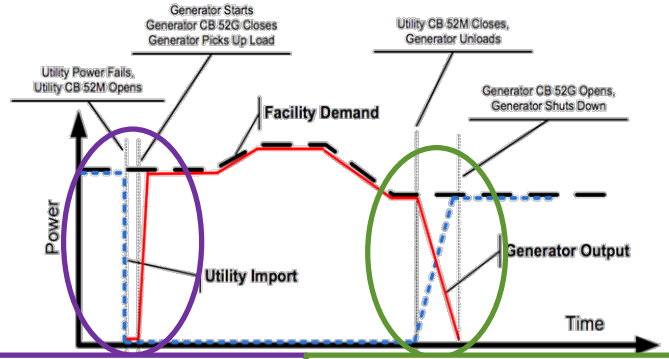


Closed transition utility -> island

Closed transition island -> utility

Open Transition

- Unplanned sequence after utility outage
- Short duration outage – 5 sec to 10 mins+
- Expensive and complex to avoid outage



Open transition utility -> island

Closed transition island -> utility

Islanded Operation Examples

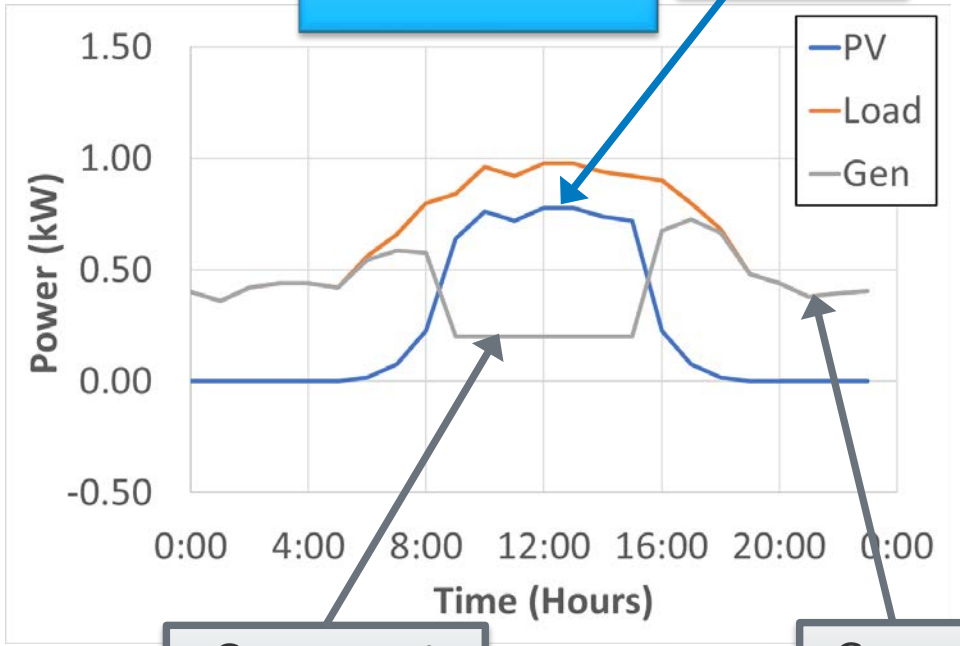
Example Gen + PV

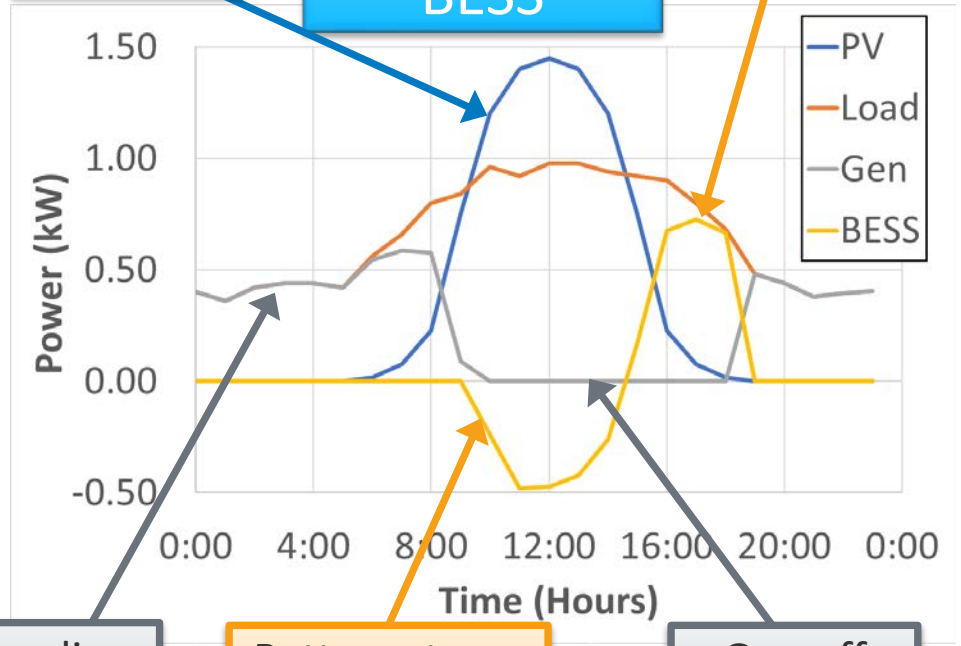
PV curtailed

PV not curtailed

Example Gen + PV + BESS

BESS discharging





Gen runs at min load

Gen supplies load at night

Battery stores extra PV

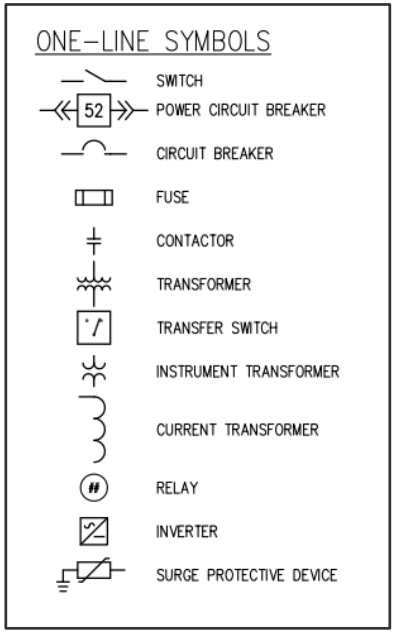
Gen off during day

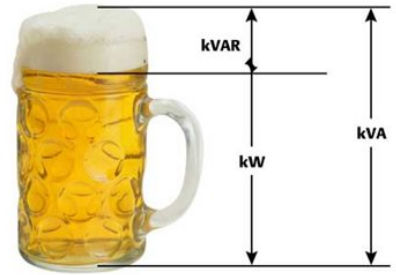
MG Components

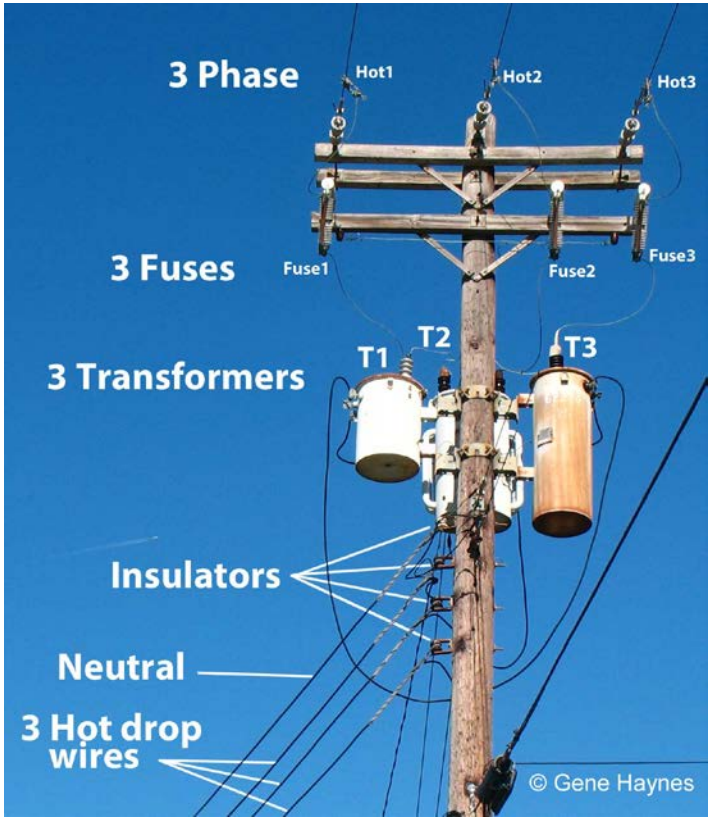
Components of Microgrids

Components

- Generation
- Energy storage
- Loads
- Lines
- Switching Devices
  - Disconnect switch
  - Automatic transfer switch (ATS)
- Protection Devices
  - Circuit breaker
  - Recloser
  - Fuses
- Power Factor Correction
  - Voltage regulator
  - Capacitor

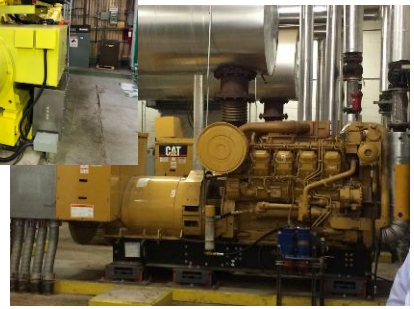






Typical Sources

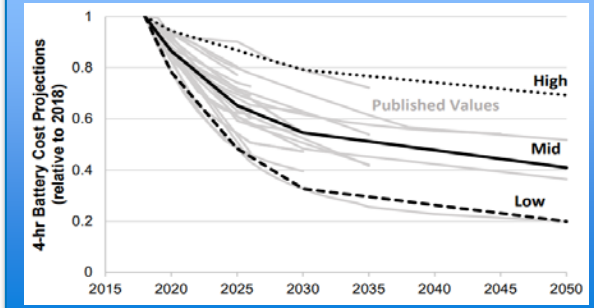
- **Fuel generators:**
  - Can grid-form
  - Fuel considerations:
    - Diesels are more stable
    - NG lower emissions
  - Load share easily
- **Wind/PV:**
  - Can't grid-form
  - Highly variable
  - Curtailable
- **Hydro:**
  - Sometimes grid-form
  - Less variable



- **Energy Storage:**
  - Can grid-form
  - Storage options:
    - Batteries
    - Flywheel
    - Pumped hydro
    - Thermal
    - Flow
  - kW rating
    - Affects stability
    - Enables diesel-off
    - Enables more renewable penetration
  - kWh rating
    - Duration
    - Reduces fuel usage

Energy Storage

Costs are decreasing



Use-cases are Expanding

- Demand management
- Time shifting
- Resilience
- Frequency regulation
- Renewable storage
- Voltage stability

Different Than a Generator

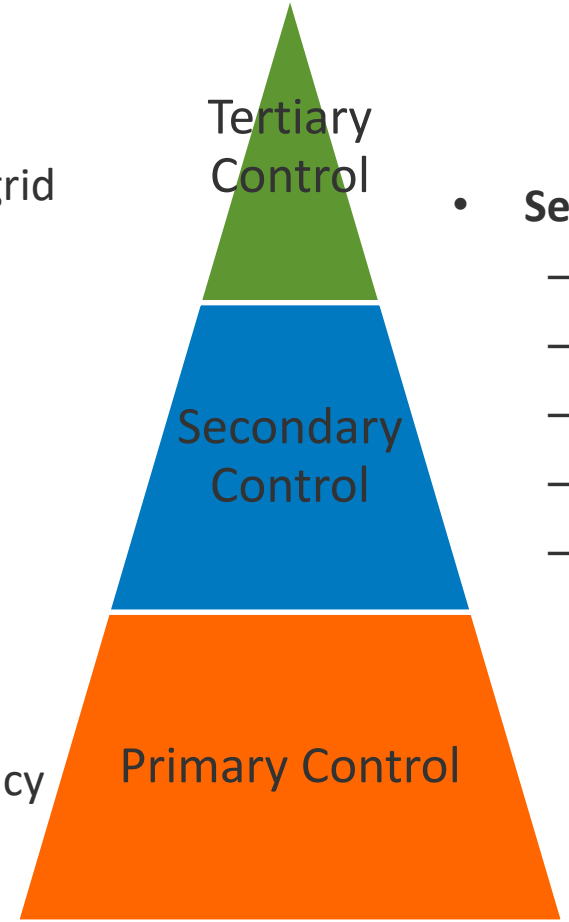
- Faster response time
- Tighter voltage and frequency control
- Much lower fault currents
- Can absorb power
- Can be programmed to emulate generator

Other Considerations

- Round trip efficiency ~90%
- Operations impact lifespan
- More complicated to control
- Storage is usually DC, grids are AC
- Made of two elements, inverter and storage

Layers of Controls

- **Tertiary Control:**
  - Slowest level (min to hr)
  - Interactions with larger grid
  - Economics
  - Weather



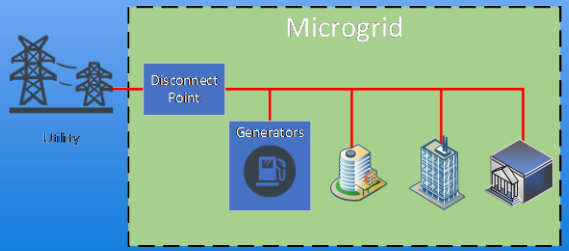
- **Secondary Control:**
  - "Microgrid Controller"
  - Medium speed (sec to min)
  - Balance loads/sources
  - Update setpoints
  - Step through sequences

- **Primary Control:**
  - Embedded controls
  - Fastest (ms to sec)
  - Stabilize voltage/frequency
  - Fault protection

Summary

Microgrid

Isolated or stand-alone grid section with sources and loads



Benefits

Resiliency

Economics

Power quality/CHP

Modes

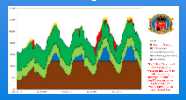
Grid-tied	Island
Freq set	Freq created
More stable	Less stable
High current	Low current

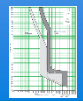
Microgrid Design

Economics

Resiliency requirements

Component sizes and locations





Components

Sources

Generator and inverter based

Energy storage

Isolation devices

Controls