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Building Resilient Microgrids:
- Integration Opportunities and Business Case Development

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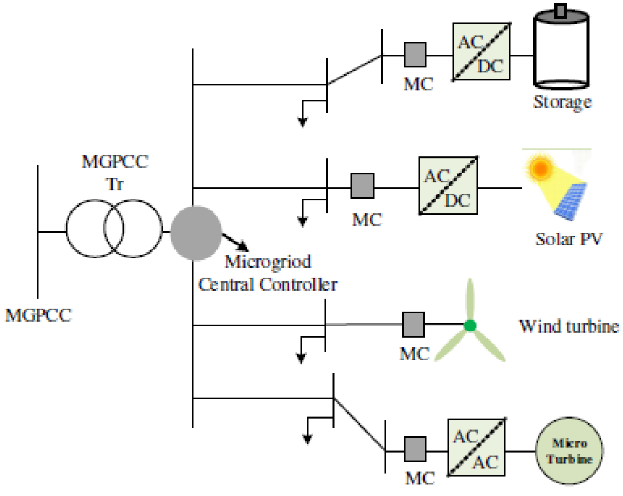
Overview of Microgrids

- What is a microgrid? A Microgrid is an integrated energy system consisting of distributed generators, energy storage, and/or flexible loads which operates as a single, autonomous grid either in parallel to or islanded from an upstream utility or other power grid.
- Why is it important? Due to increased needs for energy security and resiliency of power supply, end consumers are more concerned with power quality and reliability in recent years.
- How can microgrids Help? Supplying power to critical infrastructures such as hospitals, military bases, data centers, and communication infrastructures during upstream grid outages by operating in islanded mode, providing other services while in grid-connected mode, microgrids help realize optimal use of distributed energy resources.
- What are other benefits? Optimally manage distributed generations, energy storage systems, and responsive loads in both normal as well as abnormal operating conditions. During normal operating conditions for either grid connected or islanded, energy efficiency and economic operations are typical considerations. However, during abnormal operating conditions and transitions, technical aspects such as stability, resiliency, and energy security become primary concerns.



Some Reasons Why Potential Users Want Microgrids and Distributed Energy Resources

- More control over power/energy supply, energy security/resiliency
- Reliability, availability, resiliency improvement; more fuel sources, distributed
- Particular use cases (i.e. fuel use/shipment reductions, demand management, voltage support, power quality improvements/flexibility, T&D congestion mgmt., upgrade mitigation, outage mgmt./backup power, etc.)
- Energy management and use control
- Improved power system knowledge/metering and control
- Optimize investments, asset sizing and improve system architectures, usability (i.e. UPS with lead acid batteries and diesel gensets vs. more flexible energy storage and genset options)
- Enable optimal loading on gensets, non-spinning reserve, turn off gensets at times and still pick up load changes, allow time to spin up additional gensets
- Green energy goals and knowledge of energy supply

Sampling of Project Photos

Many Distributed Generation Resource Options

- Solar, wind, run-of-river/stream/canal hydro, micro-hydro, geothermal, GSHP
- Natural Gas (CHP, CCP, gas turbines, internal combustion, microturbines, fuel cells)
- Diesel, other fuels (LPG, CNG, LNG, etc.; up and coming: hydrogen, ammonia, synfuels, small/microreactor nuclear)
- Battery storage (Li-ion, flow batteries, advanced lead acid, NiCd or NiMH, etc.)
  - Many potential applications and value streams for battery storage (frequency and voltage regulation, peak shaving, capacity, congestion management, backup power and outage reduction/management, etc.)
- Thermal storage, building thermal and load management (ice, chilled water, hot water, building temp controls, thermal mass, solar heating (active and passive), efficient systems and controls, etc.)
  - Include energy efficiency measures and designs

Energy balance, resource characteristics and asset choices are key

- develop business case and economics, <u>define requirements effectively!</u>
- systems planning, integration and controls choices are critical (i.e. acquire equipment with the capabilities and functionality needed now or in future, such as inverters that can operate in islanded modes, output control, etc.)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Resiliency Considerations

- Potentials for supply chain impacts depending on resource types and related infrastructure/systems
- Potentials for cost impacts due to outages or supply chain impacts

- Need to start valuing and funding resiliency more directly (improved resiliency and availability is typically worth 20% to 300+% more than the regular blended cost of electricity)

- Some energy resource types have significant potentials for price volatility, plus future cost impact considerations, especially for carbon-based fuels
- Increasing potential for use-cases utilizing energy storage combined with other assets and advanced controls.



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Microgrid System Architecture Optimization

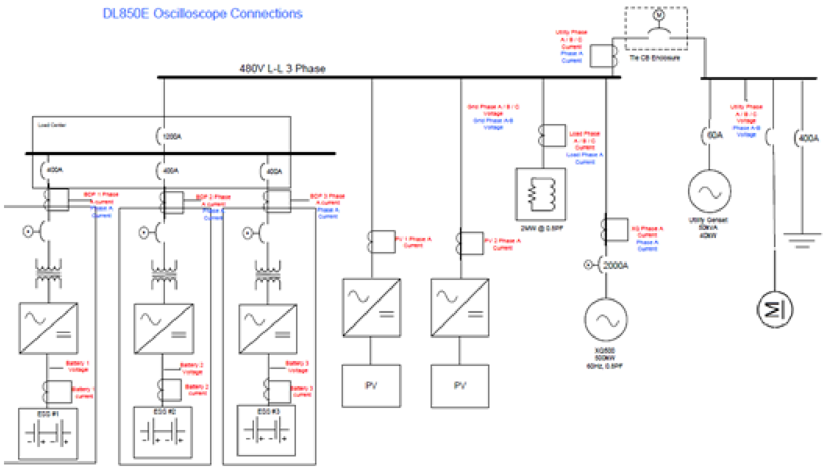
- Analyze and determine desired power and energy penetration levels of variable generation (i.e. solar PV), load profiles, generation profiles, fueled generator load levels, amounts of storage and load control to enable designs for stable and optimal control, fuel use/durations and mission/energy security
  - Storage considerations may include fuel tanks, batteries, natural gas systems (pipelines, bulk storage), hydro, LPG/CNG/LNG, hydrogen, thermal, etc, etc.

- Are you designing for times of fueled generation off, certain number of spinning generators always on, set amounts of spinning reserve, or other?
- What control functions are available in inverters, fueled gensets, secondary control systems, etc that will allow for optimal system integration/control (i.e. droop, isochronous, advanced droop coordination, PMU-based control, etc)
  - or what modifications need to be developed or added to the primary and secondary control systems to achieve desired results for all modes/use-cases

- Consideration of integration of other devices to improve stability, operability
  - Secondary, tertiary control loops/algorithms
  - Battery storage systems with advanced inverter functions/controls
  - Flywheels, SVAR, DVAR, and/or switched components for Volt/VAR control
- System protection and electrical power improvements
  - Considerations are somewhat different when generation is distributed closer to loads and connected within distribution panels

Microgrid System Architecture Optimization, continued

- Fueled gensets all the same sizes, or varying sizes to match up with net load profiles better?
- Make sure storage and genset combinations can pick up and manage any swings or steps in variable generation and loads. Sizing of these is critical, for both power and energy capacities, and for protection design and inrush considerations.



Microgrid Control Considerations

- Inverter control options: PQ control, MPPT, P-f and Q-V control (droop), closed-loop voltage and frequency control
- Controls approach when combining inverter based generation and storage with spinning generation; primary, secondary and tertiary algorithms
- Some microgrid operation and control use-case categories:
  - Frequency control
  - Voltage control (grid-connected and islanded)
  - Energy management (grid-connected and islanded)
  - Ancillary services (grid-connected)
  - Grid-connected to islanded transitions, intentional and unintentional
  - Islanding to grid-connected transitions
  - Protection (can include adaptive approaches)
  - Black start
  - User interface and data management

FE Warren AFB wind turbines: utilized for microgrid energy security and controls demonstration, 2009.

Ascension Island: wind, diesel, synchonous generator, desalination hybrid energy microgrid system.

INL interest in Microgrids with ESS and control improvements

- Significant background in battery testing and R&D for EV programs (DOE, USABC, etc.)
- DOD and other micro/island grid work (R&D, testing, development, implementation support)
- Improving integration technologies/options for renewable energy, DERs
- Falling costs and increasing penetration levels (wind, solar, ESS's, EV's, heat pump systems, other electrification technology trends)
  - Need for new technologies/resources to optimize and manage power systems controls, O&M and costs, as systems move toward lower carbon inputs/outputs, more variability.

- Installations w/ high energy security needs, continuing to invest in backup power systems, UPS's, etc. With new technologies, improved system architectures need to be considered.
- Energy storage, load control/shifting can enable improved use of fueled generation resources, stretch fuel supplies, improve reserves and dispatch options, and in many cases lead to improved long-term business case/economics.
  - Also ability to push renewable energy penetration percentages over 20-30%, and power penetration over 100% at times.

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Microgrids with ESS, continued:

- Aspects of energy security, resiliency, multiple/diverse fuel/generation resources, and stretching of fuel supplies.
  - Users with these types of power/energy assets could offer interesting business and technical interaction potential with serving utilities.
- Critical loads often need higher RAM than typical utility feed can supply (i.e. 5+ nines of availability vs. 2-4 nines). Describe some of the ways to analyze and accomplish this.
- Economic considerations can get quite interesting for critical assets/missions (determining true costs of outages, systems costs and potential savings streams, etc.).

- Can we start figuring out ways to get these services from utilities or private industry? Or improve market/rate structures to better interact with service utilities or control areas with the resilient assets being developed?
- I.e., there are many needs for market changes to optimize use, pricing and benefits of DER's and energy storage.

Thank you!!!!!

Questions ????

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Extra Slides

Distributed Energy and Grid Systems Integration

- Mission
  - Perform scientific research and engineering to enable development, deployment and integration of distributed energy, microgrids and power system technologies
  - Resource Areas
    - Wind, Solar Energy
    - Controls/comms requirements, integration/ops guidance
    - Island and backup power grids (diesel, other fuel types, renewables integration)
    - Power Systems (including micro/smart grids, energy storage)
    - Grid integration and modeling, security, RAM/PRA and reliability
    - Bio/waste energy
    - Geothermal Energy
    - Hydropower, Nuclear

- INL has 30+ years of engineering/R&D experience w/ DOD/DOE high reliability power systems, backup power/energy security, renewable energy integration/microgrids, typically as owner's engineering support on govt side.

Small sampling of other power systems, renewable energy and island-microgrid projects

- UT DOD Site – 2 MW PV, diesel powerplant upgrades, power studies and upgrades, multiple other energy projects, upcoming 2 MW PV+storage and wind turbine or additional PV, plus microgrid with battery storage.
- UT DOD Site – 1.5MW solar CSP, 1.5 and 1.8 MW wind turbines, power studies and upgrades, multiple other energy projects, microgrid w/ battery storage, upcoming diesel to NG genset upgrade.
- Ascension Island – Wind-diesel island power system, plus controls, desalination and PQ management systems.