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Senior Electrical Engineer

MARVEL Review:

Resilient Energy Microgrid Integration Overview

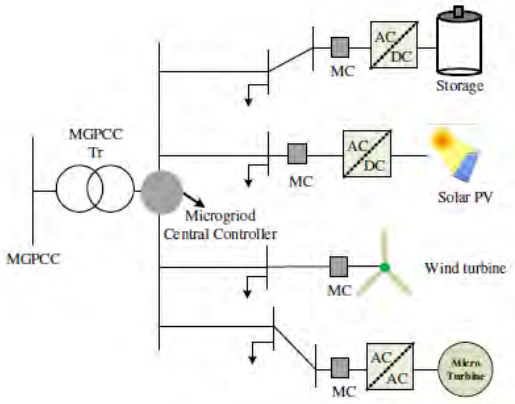
Idaho National Laboratory

Introduction – Porter Hill

- Electrical Power Engineer at INL (over 15 years)
  - Energy & Grid System Integration
  - Support military installations become more resilient
  - SME support for large scale microgirds at several military installations
  - Designed and deployed first microgrid in Middle East and continue to monitor the system
  - Research focus
    - Microgrid controls research between DERs and grid
    - Increase the inverter-based generation penetration onto the power grid

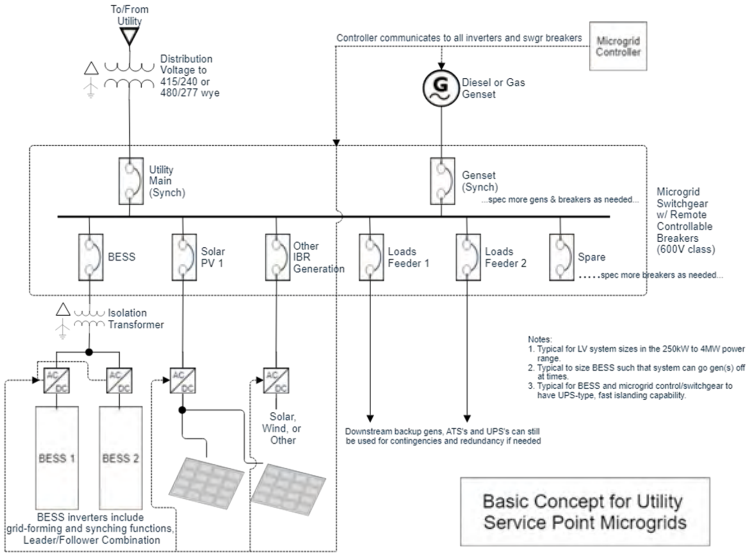
Overview of Microgrids

- 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.



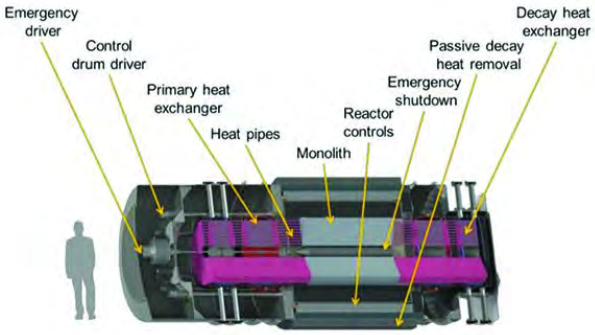
Introduction to Clean Energy Microgrid Systems

- Distributed Generation Resource Options
  - Renewable Energy Generators
    - Solar,
    - Wind,
    - Hydro (dams, run of river)
  - Fuel based generations
    - Nuclear
    - Natural Gas
    - Diesel
  - Storage
    - Battery
    - Thermal



Many opportunities for early/pre commercial product and unique integrated systems demonstration, testing: DOD, other users with high energy costs, diesel usage, security/resiliency needs

- Multiple CONUS and OCONUS demonstration and R&D projects occurring FY21-FY22, others proposed for FY23 and beyond
- Several of the projects include more deployable/modular systems and designs better matched to application and environment. Various solar PV, deployable wind, energy storage and microgrid concepts being developed or proposed.
- DOD PELE Nuclear Microreactors involvement
- Other microreactor developments, including MARVEL & other industry collaborations (Oklo, X-energy, Westinghouse, TerraPower, etc.)



MARVEL reactor concept with Stirling engines.

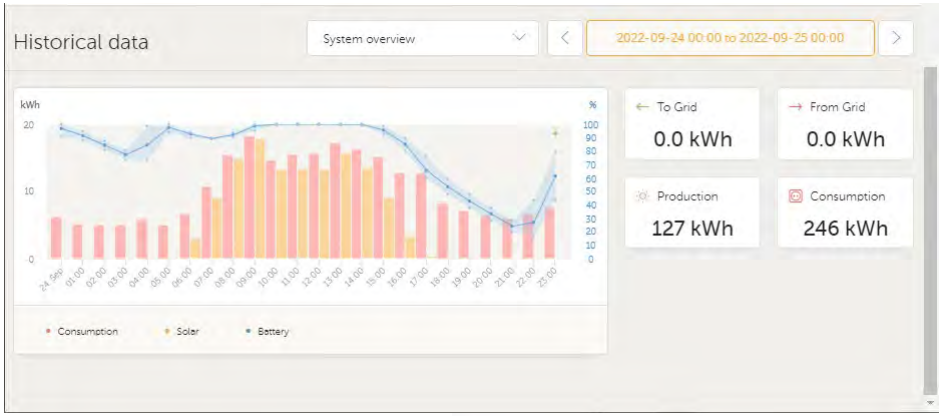
RAPID-MIB, i.e. Microgrid-in-a-Box

- This is a first-of-a-kind system for portable, medium-high energy density power grid storage applications with a size that can power a 125kW-250kW sized commercial/end-user building/facility, for multiple hours, with switchable power ratings between 415/230VAC, 50Hz, three-phase to 480/277VAC, 60Hz three-phase, and including advanced controls for specified functions during both grid-tied and islanded operations that are suitable for military or commercial/utility applications.
- The control mode features available in this system are newly released, and allow for stacked mode uses and droop settings (or fast frequency-Watt and/or Volt-Var) adjustments during operations with communications and commands from advanced secondary/tertiary control systems.
- System can stay in voltage-source in most applications, or switched to P-Q or other modes as needed.
- Portable and deployable energy blocks are connected into and managed by the microgrid controls system as needed/available. These can include solar, wind, micro-nuclear, fueled resources, hydrogen-based, etc.
- RAPID-MIB stands for Relocatable/ Resiliency Alternative Power Improvement for Distribution – Microgrid In a Box

INL worked with two public utilities to demonstrate use of small hydropower to increase local grid resilience

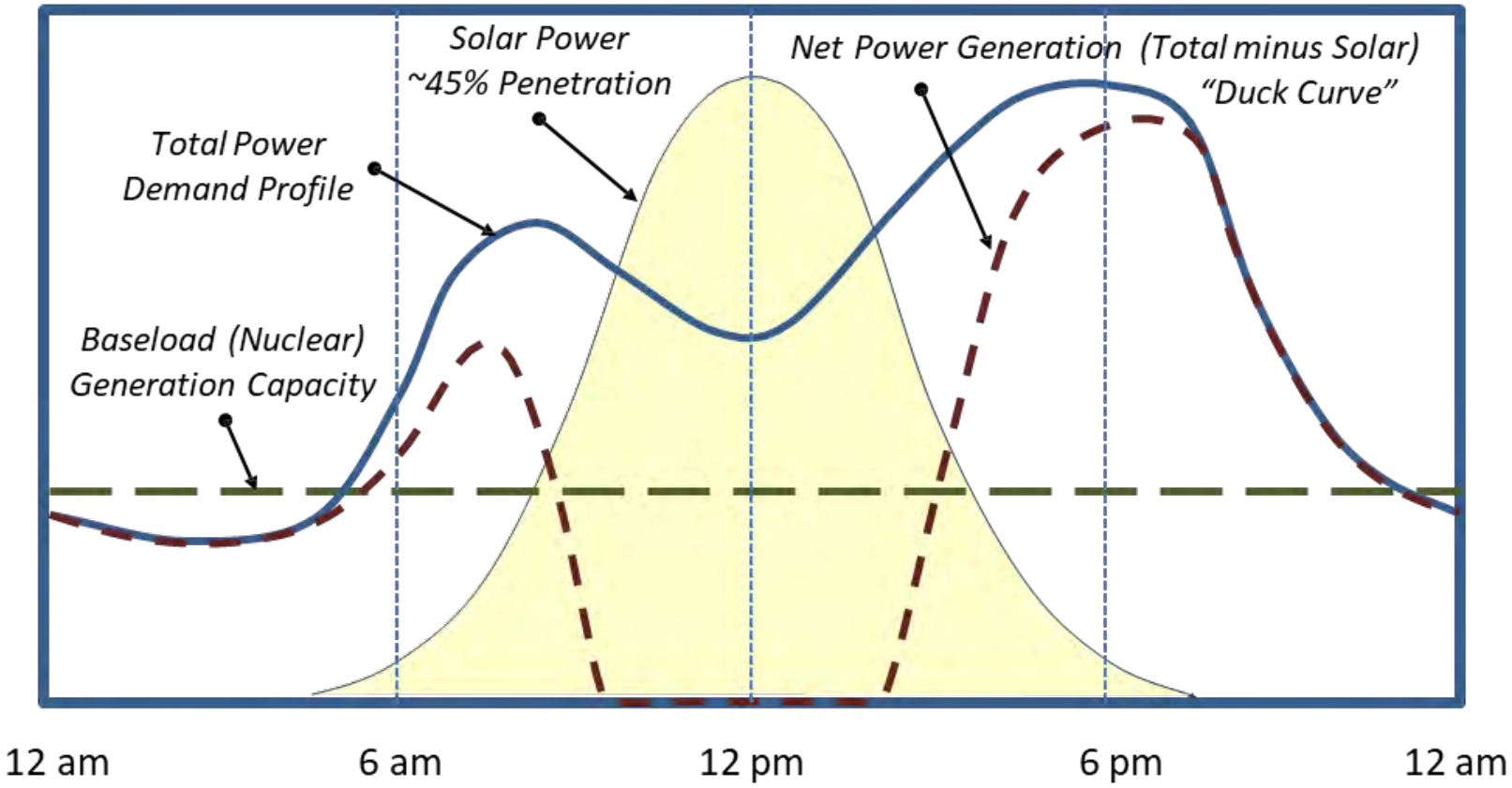
- INL innovating on hydropower controls, hybridization with batteries, and local asset networking
- Idaho Falls Power (March 2021) demonstrated ability to support 8 MW of load during emergencies
- Fall River Electric (July 2023) showed more autonomous controls and “Microgrid in a Box”

Successfully installing field implementations in Kuwait

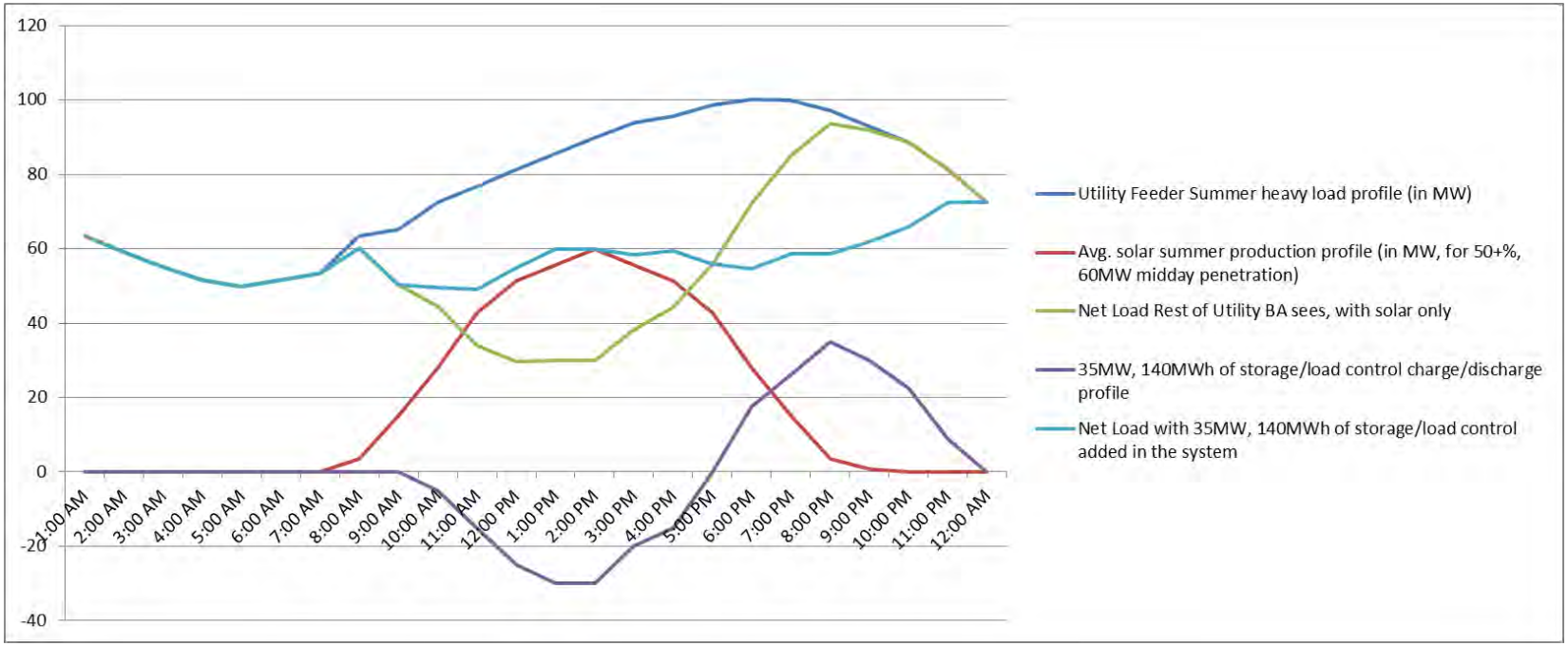


- Three projects that are part of the Operational Energy program managed through INL on behalf of the US Army Central Command (USARCENT) successfully completed their initial field implementations.
  - This occurred on two military installations in Kuwait.
  - INL team members involved include B. Turk, K. Myers, P. Hill, M. Shurtliff and J. Bush.
- The first project successfully guided the first hybrid microgrid implementation for the US in Kuwait, using advanced inverters, battery storage and specialized solar photovoltaic implementations.
  - This microgrid will operate with a higher than 60% penetration of renewable energy.
  - It will operate on battery and solar only for multiple days in a row.
- When the battery gets low, the generator will be automatically called to supply the load and recharge the battery.

Introduction to Clean Energy
Solar Energy Typical “duck curve”

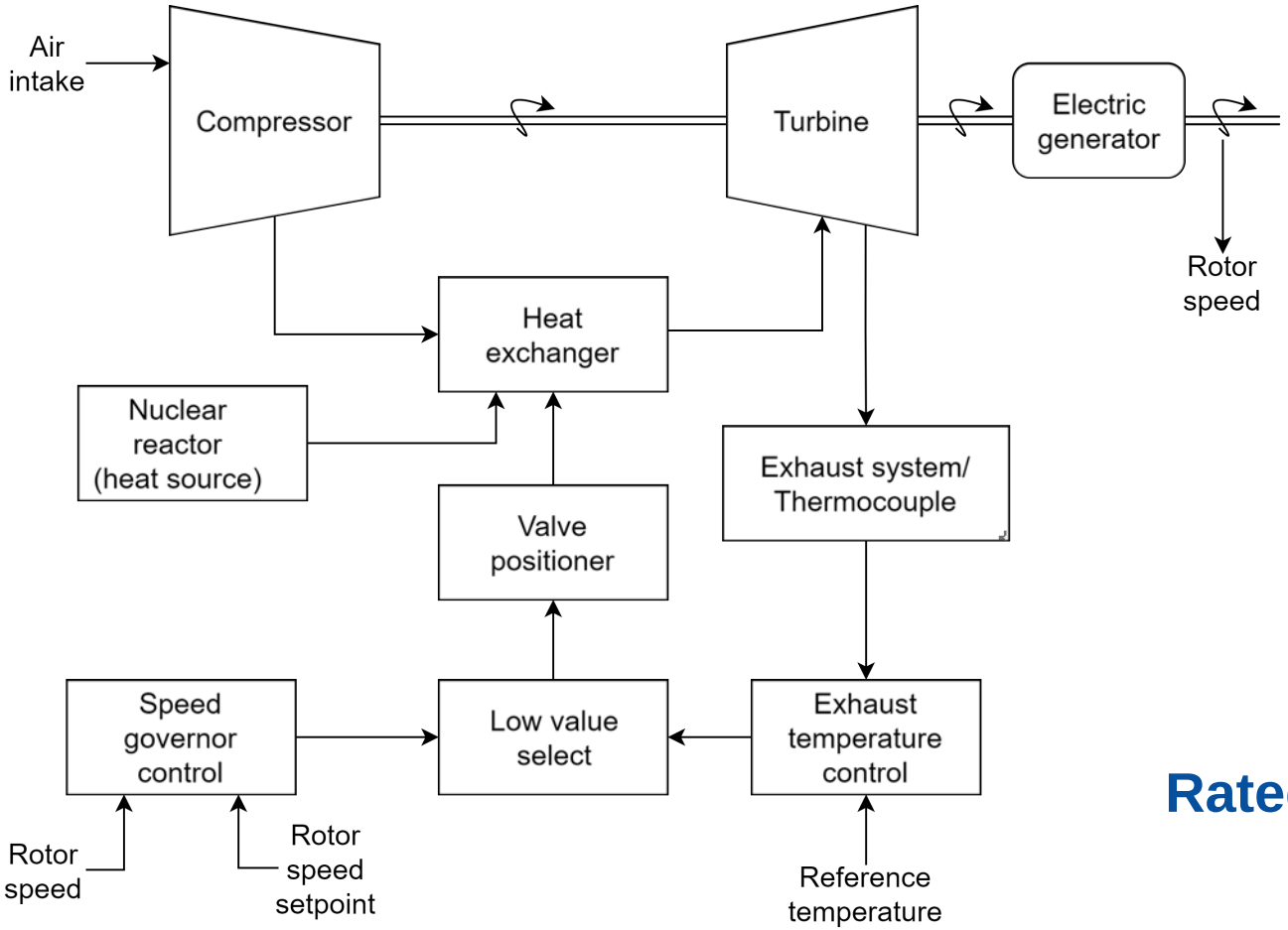


Introduction to Clean Energy Microgrid Systems



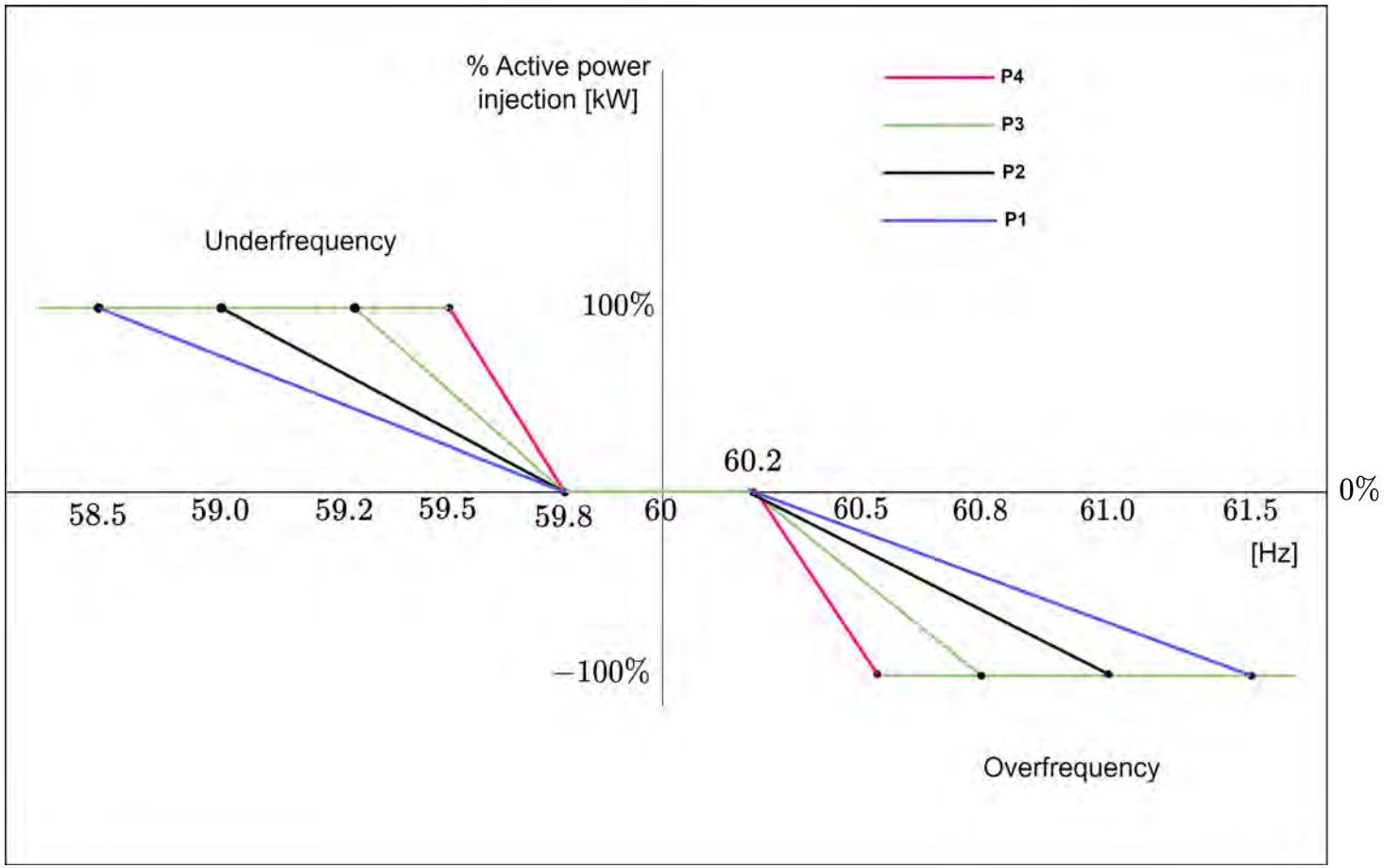
Above: extreme example of 50+% solar penetration, storage energy content of about 50% of solar energy content (daily average over course of year).

Air Brayton Cycle Turbine with a Governor Control



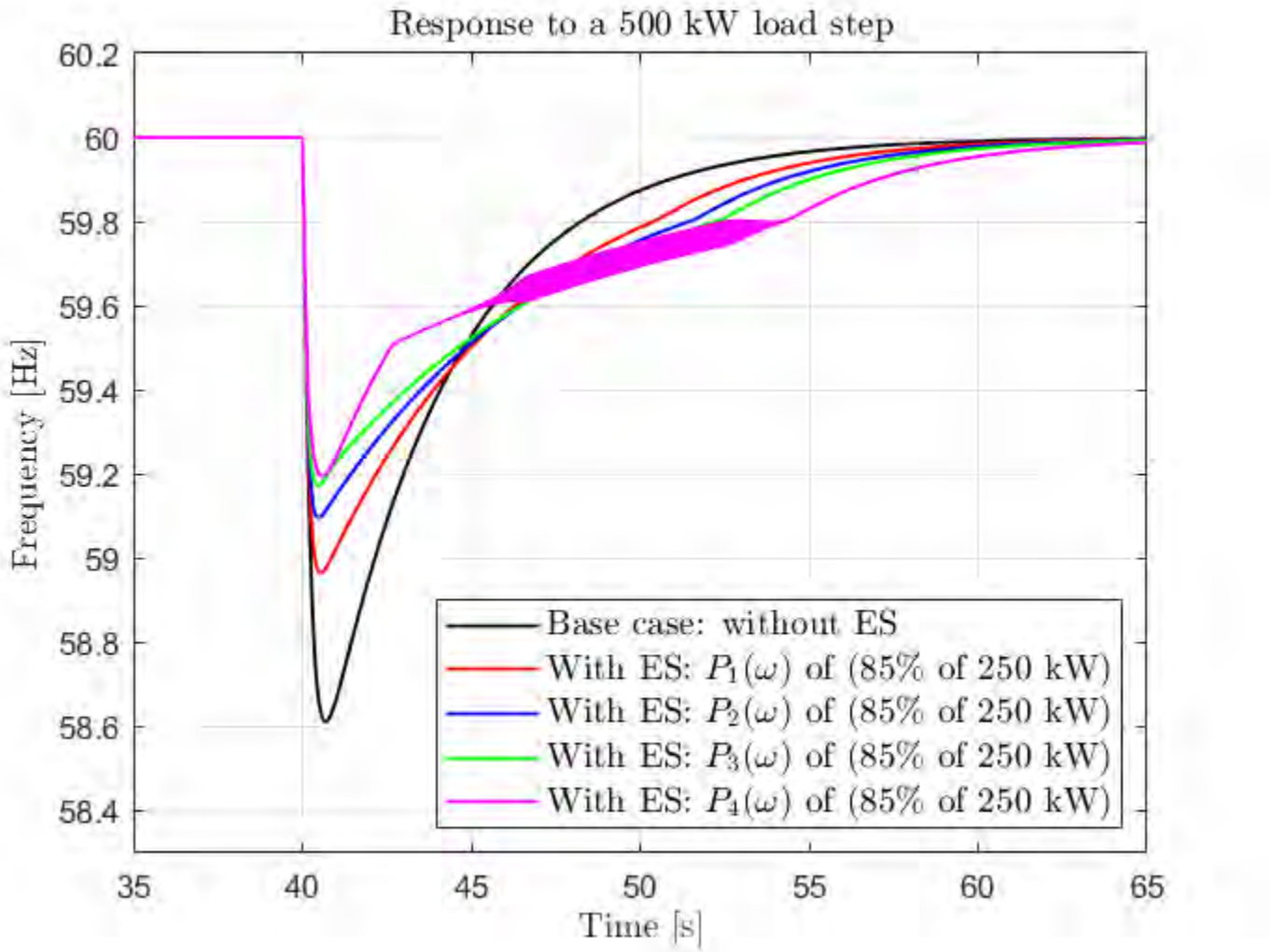
Rated design: 2 MW

F-Watt Curves Used



- The rate of power injection increases from f-Watt curve P1 to P4.

Frequency Response



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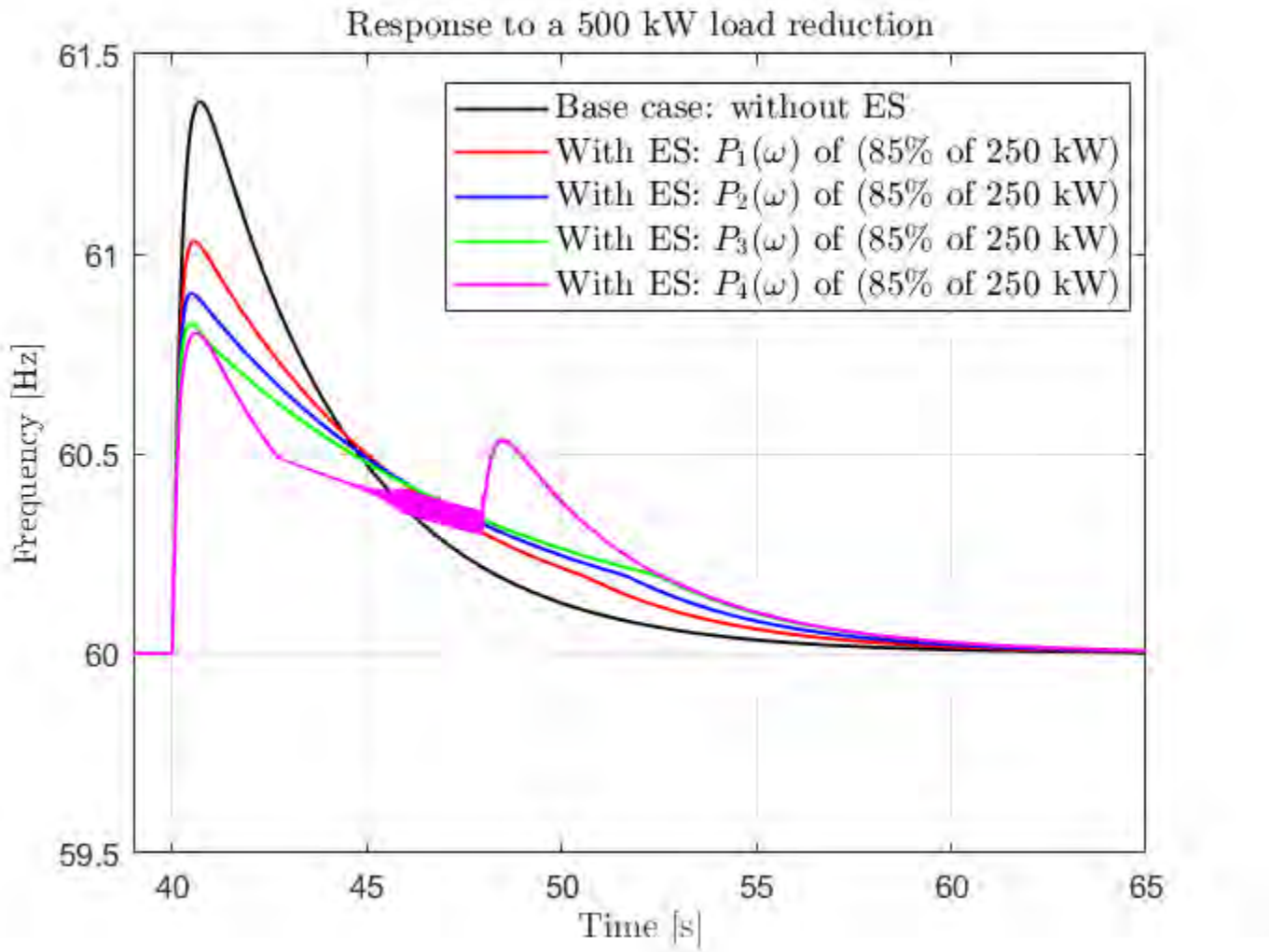

Conclusions

- The response of an air Brayton cycle-based generator can be improved significantly with microgrid-in-the-box (i.e., a battery energy storage).
- Systems response improves as the slope of the frequency-Watt curves increases from P1 to P4.
- Energy storage injection increases with improved performance.

Questions and Contact Information

Energy and Grid System Integration

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