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High Penetration Microgrids Providing Grid Stability Using Frequency-Watt Control Presentation

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Changing the World's Energy Future

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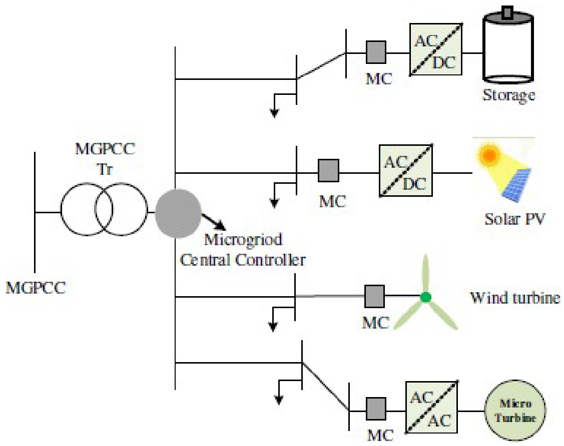
Presentation Outline

- Overview of Microgrids
- RAPID-MIB, i.e., Microgrid-in-a-Box
- Sampling of Energy Storage Functions
- Test Setup and F-Watt Curve
- Frequency Response to Load Step Changes
- MIB-in-the-Loop Test
- Conclusions

Overview of Microgrids

- **What is a microgrid?** 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. 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.



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

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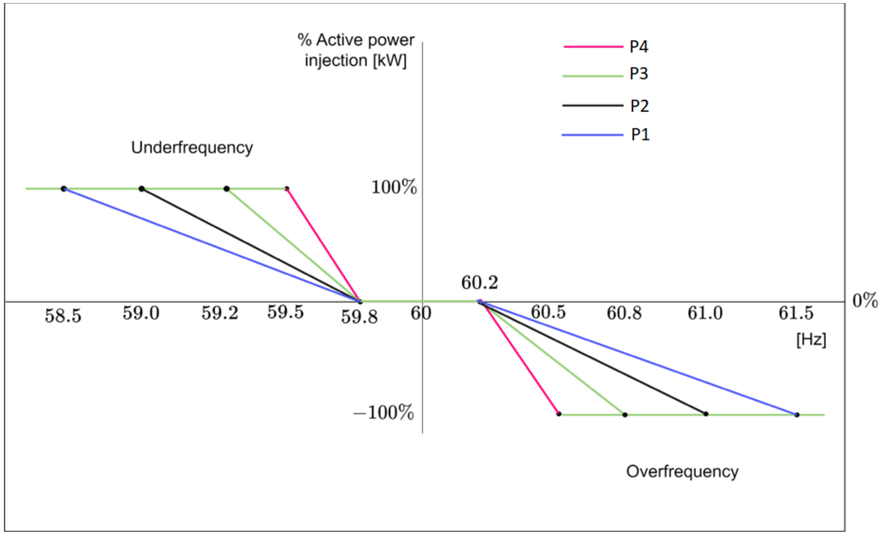
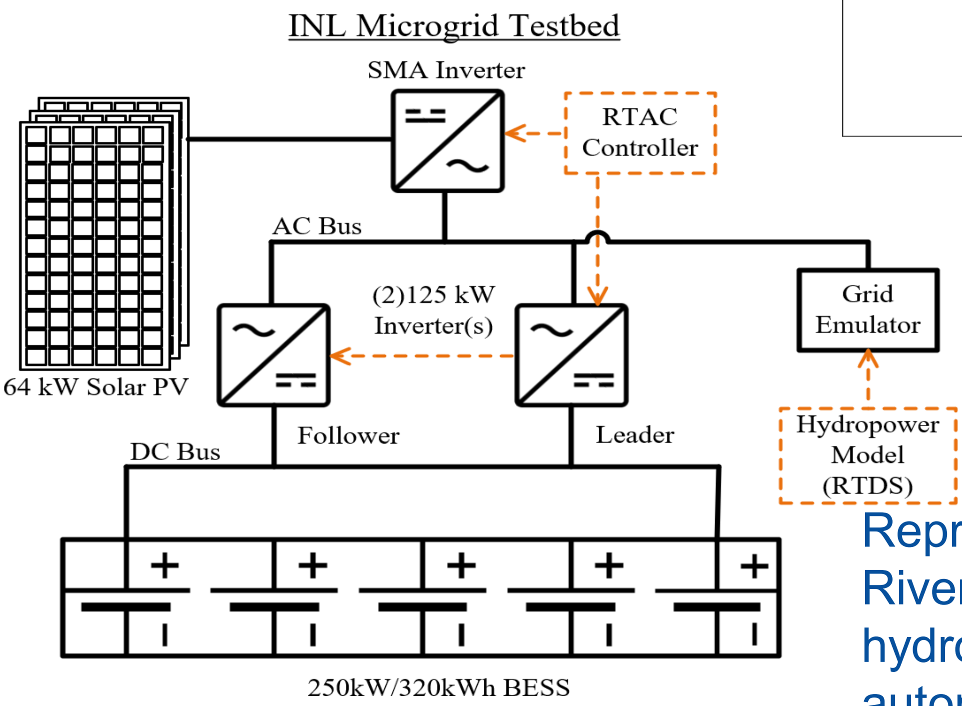
Sampling of Energy Storage Functions of RAPID-MIB

- Peak/demand management (i.e., peak shaving, demand response)
- **Frequency regulation**
- Voltage regulation
- T&D upgrade deferment
- Capacity and reserve functions
- Solar and wind power shaping, energy shifting, curtailment reduction
- Load shaping; ramp rate control
- Black start assistance
- Hybrid with gas generation to provide more responsive and cost-effective system reserves
- Enable higher penetration of renewable energy in grids, microgrids
- Improve interaction potential with Western EIM market or other BA's?
- Can BESS systems be utilized to reduce wear and tear costs on other regulating and reserve systems (i.e. hydro turbines, NG generators, etc)?

Test Setup and F-Watt Curve

- Supporting hydropower resources to provide dynamic stability of the system during islanding and blackstart.



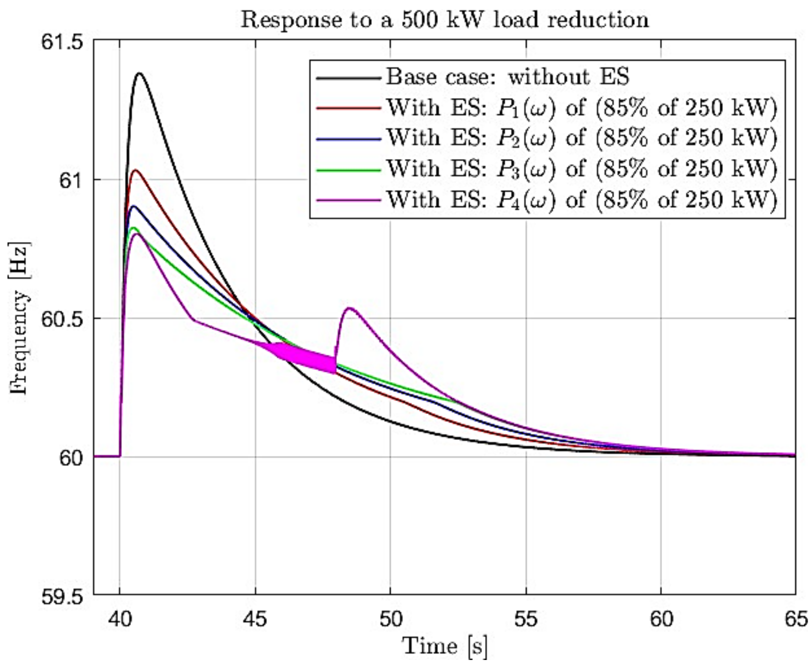


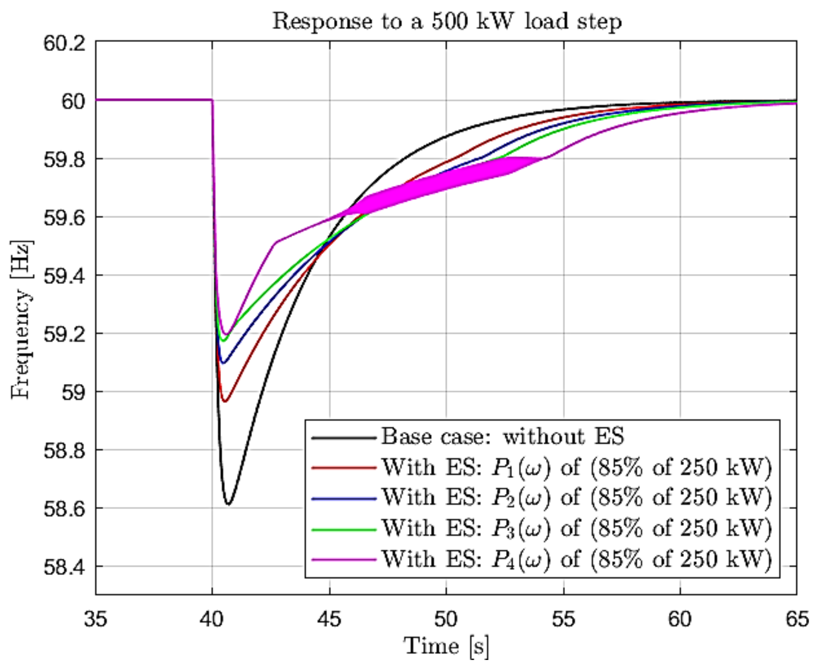
- The rate of power injection increases from f-Watt curve P1 to P4.

Representing Fall River Electric's hydropower plant for autonomous control.

Frequency Response to Load Step Changes

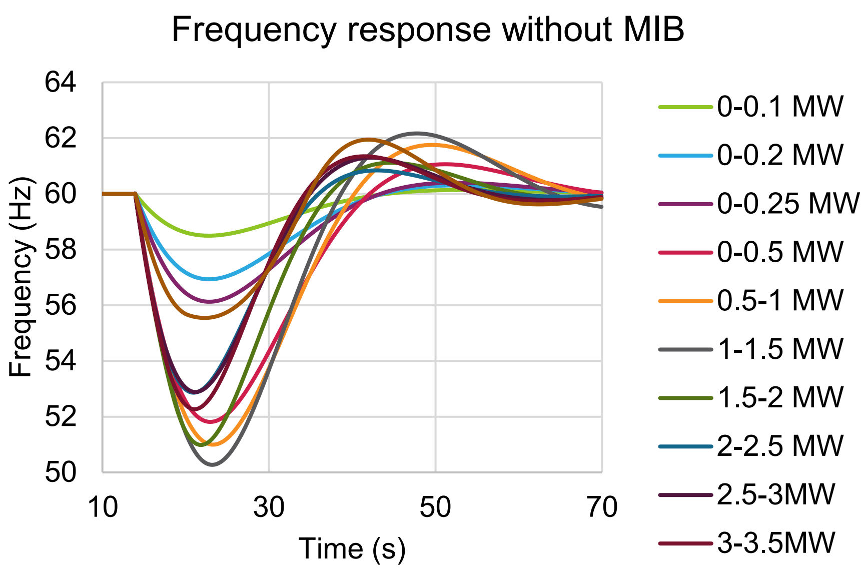
- MATLAB simulations followed-by MIB-in-the-loop testing to investigate frequency response against various Freq-Watt settings.
- Steeper slope results in faster response but can cause control stability issues.

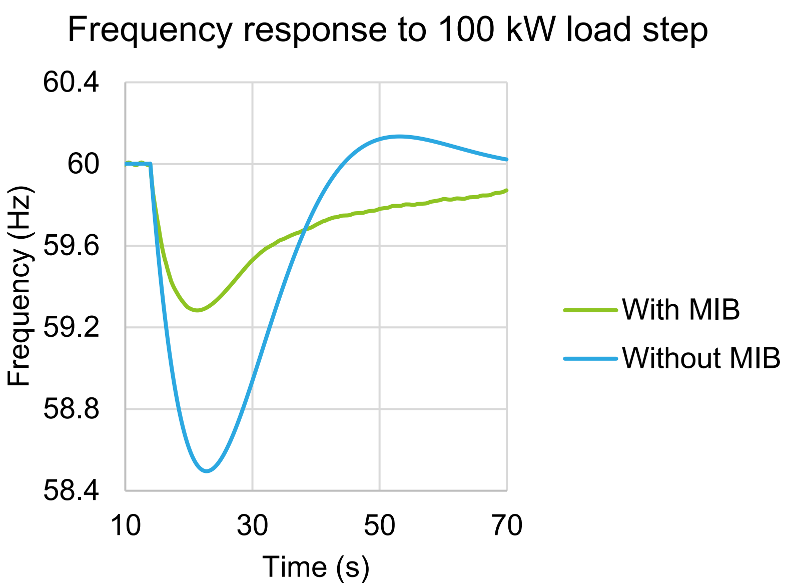




MIB-in-the-Loop Test

- Frequency response simulated using hydropower plant model in RTDS.
- The test repeated for 100 kW step using laboratory setup of MIB and hydropower plant emulated using Amatek power source.
- MIB clearly improves the frequency response by reducing initial rate of change, reducing the frequency excursion and helping the system settle faster.





This analysis was supported by the DOE Water Power Technologies Office.

Conclusions

- Online adaption of frequency-watt curve enables MIB to provide fast-frequency response depending upon the system needs.
- The frequency response of microgrid-in-a-box is tested in hardware-in-loop configuration in laboratory setup at INL prior to actual field demonstration.
- Field demonstration with Fall River Electric (July 2023) funded by DOE-WPTO.

Questions??

Thank You!!

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