Sandia National Laboratories

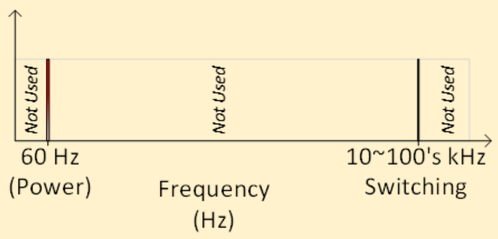
THEORETICAL FRAMEWORKS FOR PACKETIZED DELIVERY OF ENERGY

David Wilson, PI (Sandia) Ray Byrne, PM (Sandia) Connor Lehman (Sandia) Steve Glover (Sandia)
Rush Robinett III (Michigan Tech) Wayne Weaver (Michigan Tech) Trever Hassell (Michigan Tech)

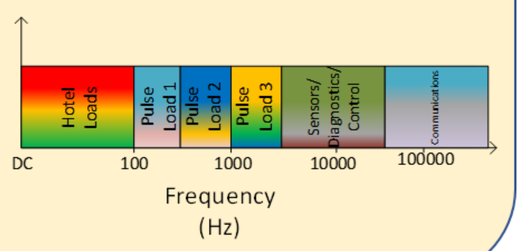
Project Description

- RES Storage-based Power Packet Networks (PPN) improves: energy surety metrics: resilience, reliability, stability, and performance of US EPG
- Result: optimal energy storage systems (batteries, capacitors, flywheels)
- RES Compatible: wind, solar, water

Today's power converter limited frequency range



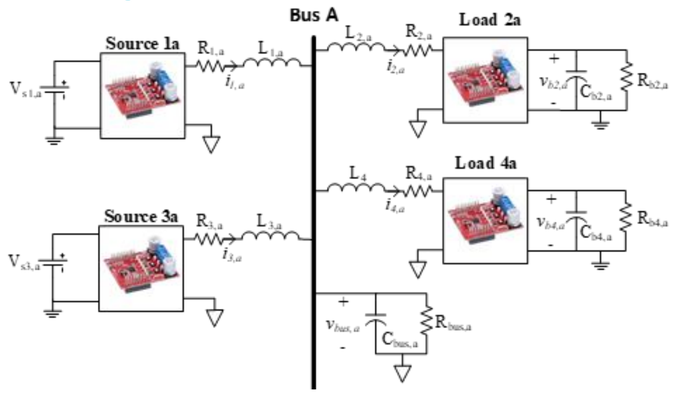
Future power converter frequency range Multi-frequency Asynchronous

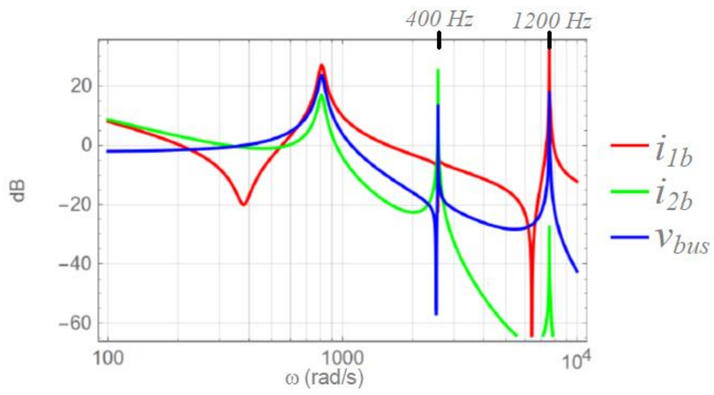


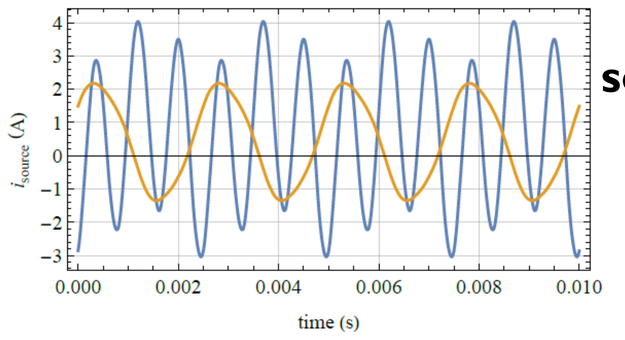
Benefits

- Operates to *limits of performance*
- Optimized ESS
- Enables: communication between system components over power lines
- Help DOE/utility operators in adoption
  - Dynamic economic conditions
  - Broader electrification
  - Support of remote and/or disadvantaged communities

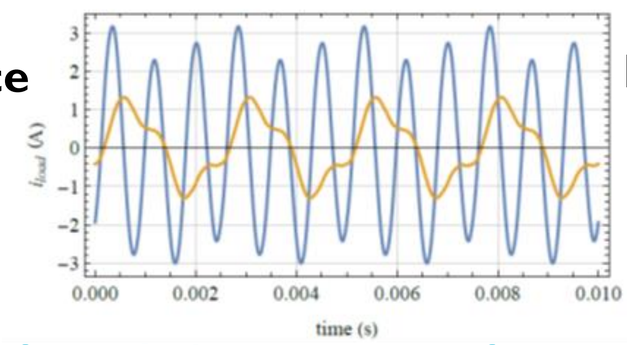
Example Four Converter Active Power Packet Network [1]







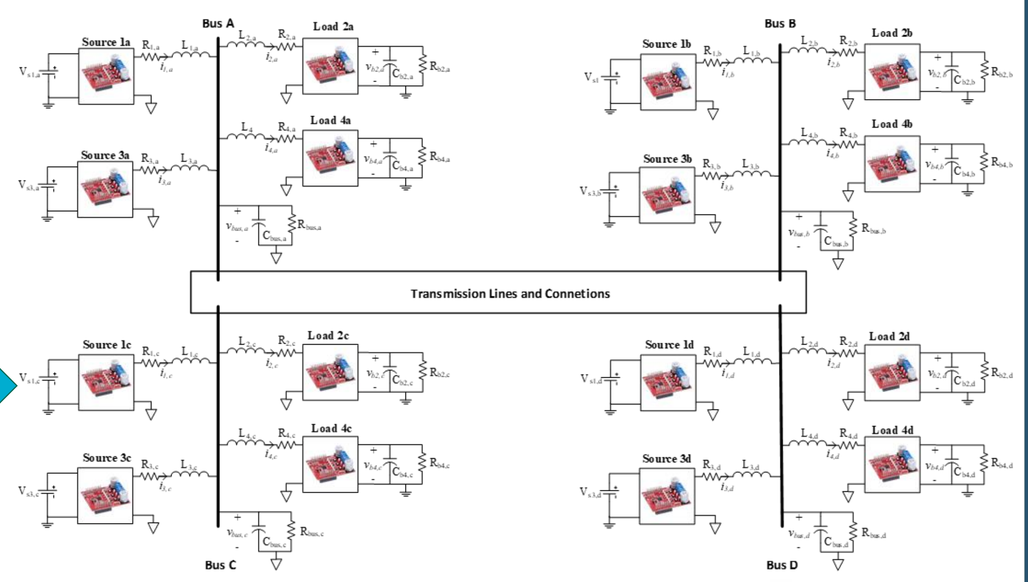
source

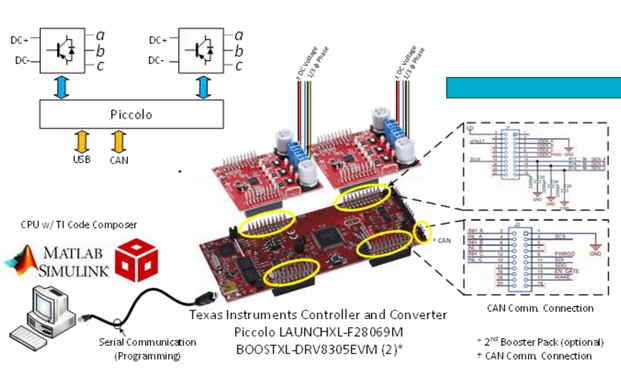


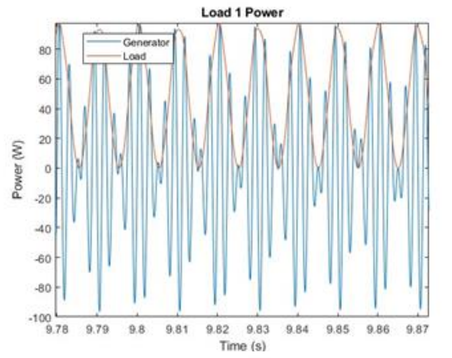
load

Modular Hardware Testbed (work-in-progress)

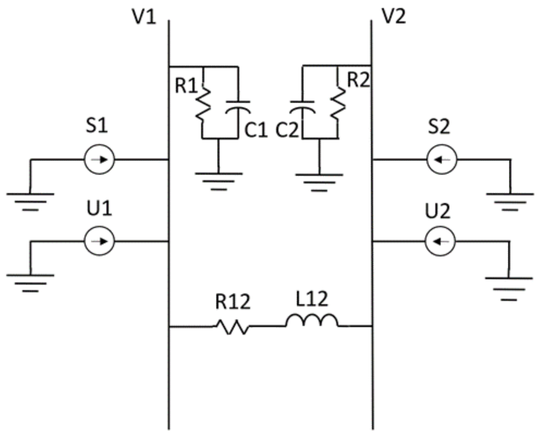
- Single phase converters: Once controller (TI Piccalo) per converter
- Local servo control w/ centralized supervisor (CAN/ethernet)



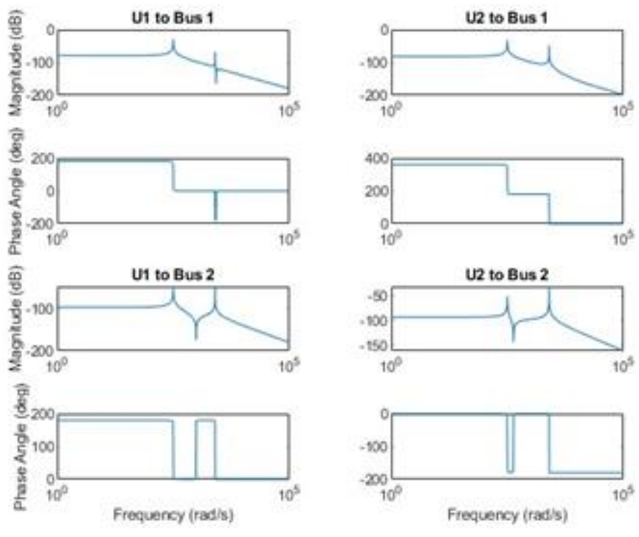




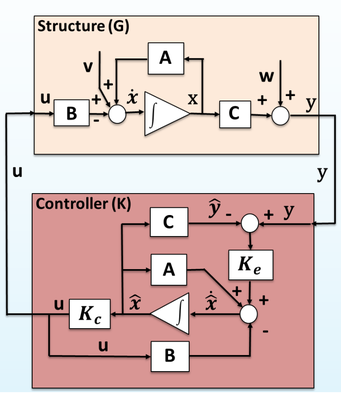
Decoupled PPN Control Design [2]



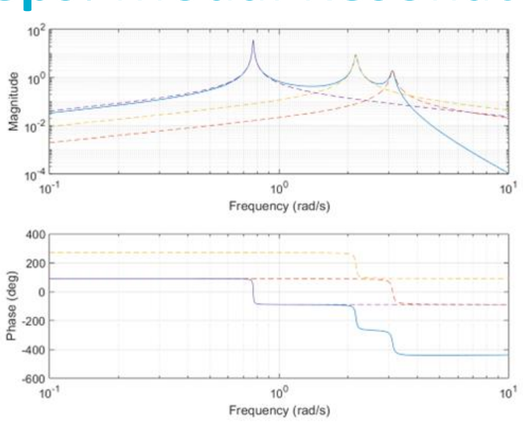
- Bus 1 50 Hz, Bus 2 400 Hz
- K_I gains selected F_{source} matches load $F_{natural}$

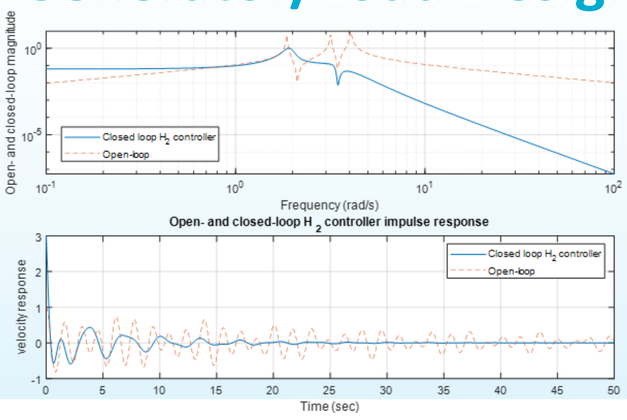


Future PPN Next Steps: Modal Resonator Generator/Load Design



Typical LQG closed-loop block diagram: Structural Dynamics





Results Published to Date

[1] Hassell, T., Weaver, W.W., Robinett III, R.D., and Wilson, D.G., Multi-Frequency Power-Channel Power Packet Networks, *IEEE Workshop on the Control and Modeling for Power Electronics, IEEE COMPEL 2023.*

[2] Lehman, C.A., Robinett III, R.D., Weaver, W.W., and Wilson, D.G., Hamiltonian-Based Power Flow and Stability Analysis on a Passively Controlled Multi-Frequency Power System, *Int'l Symposium on Power Electronics, Electrical Drives, Automation and Motion, SPEEDAM 2024.*

[3] Lehman, C., Weaver, W.W., Robinett III, R.D., and Wilson, D.G., Active Controls of a Multi-frequency Multi-bus Microgrid Network using Hamiltonian-Based Techniques, *digest accepted in ECCE* 2024.

This material is based upon work supported by the U.S. Department of Energy, Office of Electricity (OE), Energy Storage Division.

SAND2024-08757D