SAND2020-7196C

Paper No: 20PESGM0558

Sandia National Laboratories

Grid Forming Inverters for Spinning Reserve in Hybrid Diesel Microgrids

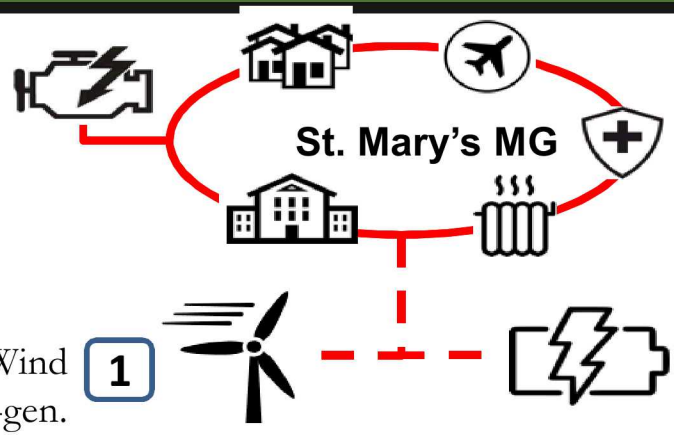
Jack Flicker

Sandia National Laboratories

jdflick@sandia.gov

IEEE PES Power & Energy Society

IEEE



- Looking in detail at rural islanded electrical system, Village of St. Mary's
  - Historically supplied by a fleet of three diesel generators
  - Diesel fuel is shipped up the Yukon river → river is impassible from August to April
    → heightened cost of electricity and shortage of diesel in the winter becomes life threatening issue
  - Drastic need for high reliability, low maintenance components that can reduce the need for diesel fuel

- Local Utility, AVEC, has been looking at a 2 part plan for St. Mary's
  - Installation of a 900 kW Type IV (increases the penetration of renewables to > 100%)
    - High penetration of variable wind → increased need for spinning
  - Instead of providing spinning reserve with diesel generators, further reduction of fuel from providing spinning reserve with energy storage and grid forming inverter (grid bridge system or GBS)
    - Allow for eventual 'diesels off' mode where the system powered entirely by wind and the GBS

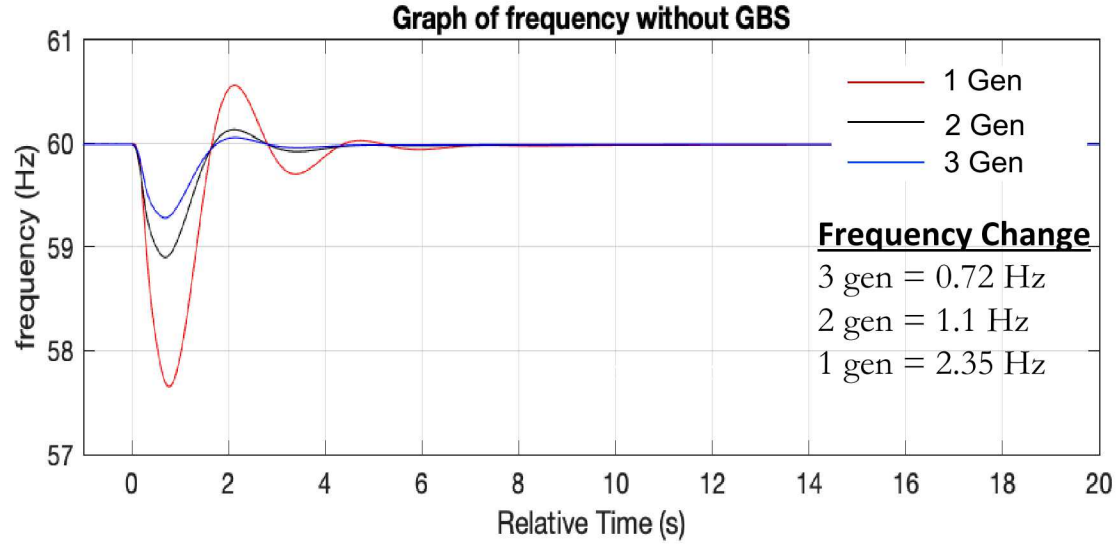
This project has been carrying out simulation and hardware-in-loop (HIL) experiments to understand how the operation of this system can improve power quality even above what is possible in the pure diesel system

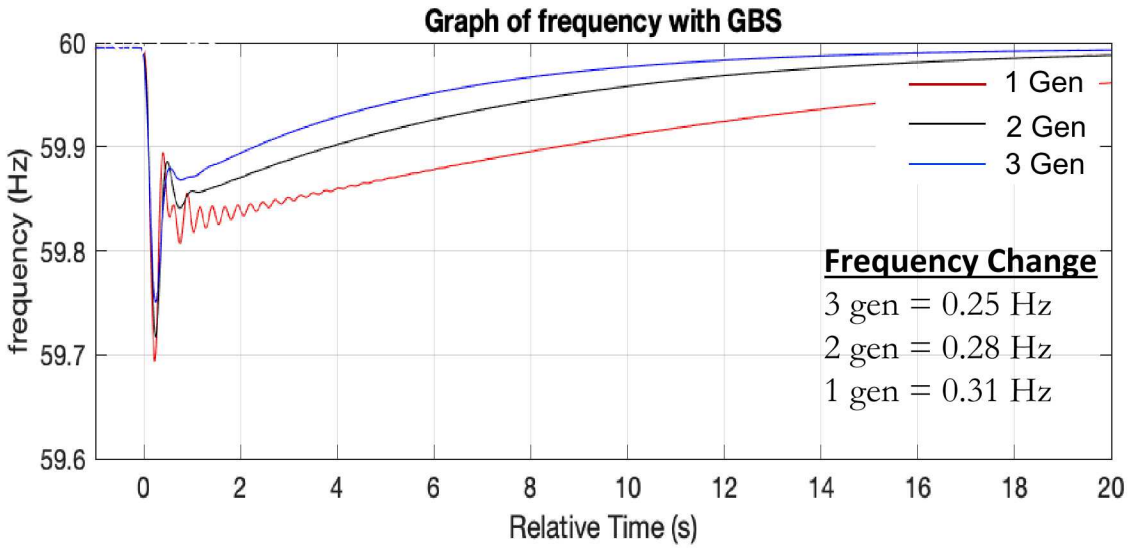
- Implemented high fidelity system simulation of St. Mary's system in Opal RT
  - Validated models for wind turbine and diesel generators
  - Fabricated GBS model with variety of control methods
    - DQ Frame with virtual impedance
    - CERTS protocol
    - Current Hysteresis

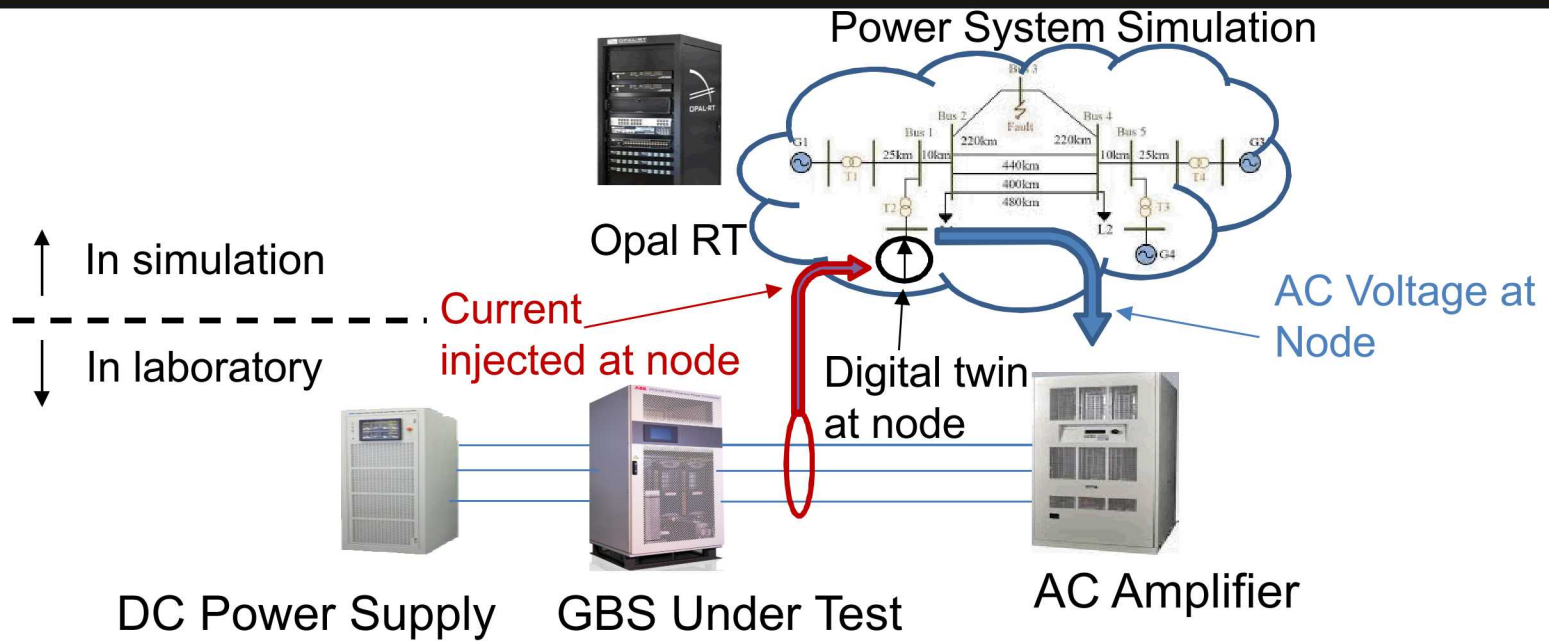
- Simulated contingency event in high-wind system with **No GBS**
  - Instantaneous wind penetration from 85% to 15% in 2s
  - Compared situation with 1, 2, and 3, generators
    - Single generator can supply remaining load
    - Other generators lightly loaded to supply spinning reserve

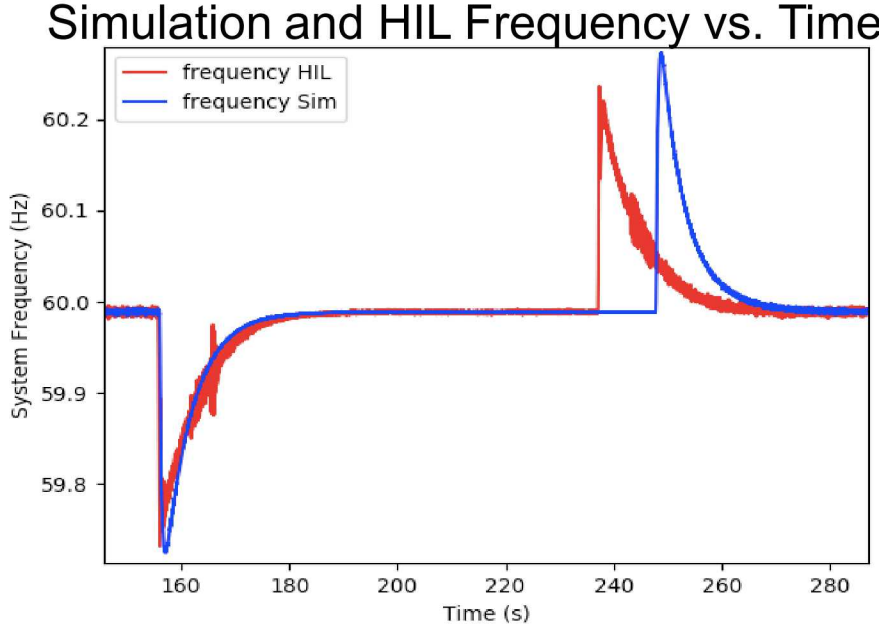
- Significant deviations in voltage and frequency with only 1 genset
  - Deviations significantly reduce as more generators are added

- Evaluated variety of control mechanisms for grid forming inverters
  - Similar results for reduced frequency/voltage deviations in system
  - Only secondary effects on voltage/frequency due to controls
  - More detail provided in paper



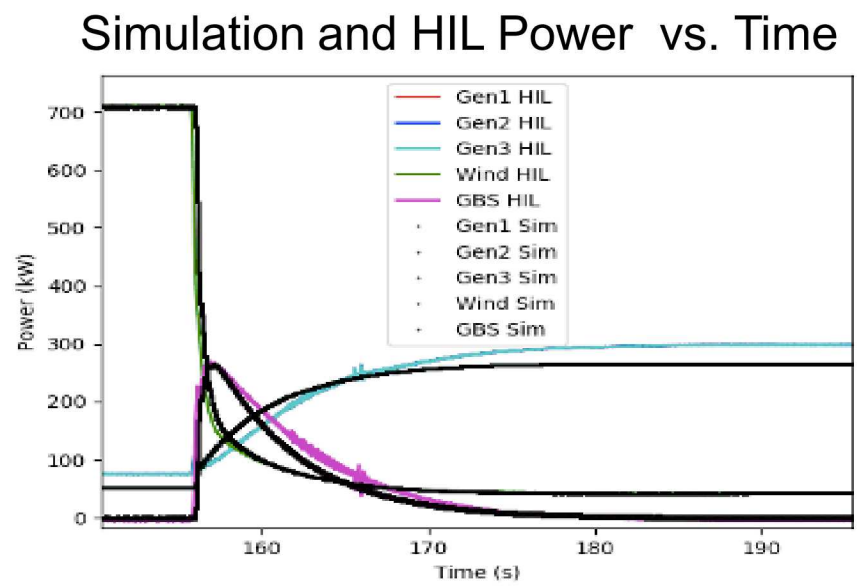






- Transient dynamic simulations show significant benefits utilizing GBS for reserve
- Next incorporate actual hardware behavior into the simulation in PHIL setup
  - Gives more realistic behavior for power electronic devices with all parasitics and inherent limitations of control schemes
- For same loss of wind scenario, good agreement between simulated GBS (blue) and measured from a real device (red)

- Real device has slightly longer decay in the power provided than what model expects, but this can be accommodated by minor change in model parameters



Conclusions/Recommendations

- Grid forming inverters for spinning reserve have been shown to increase power quality in the St. Mary's system
  - 1 Generator + GBS shows smaller frequency deviations than nominal 3 generator case

  - Successfully validated simulation results using hardware in loop for the St. Mary's model and a loss-of-wind scenario
    - Excellent match between the simulated scenarios and hardware-based scenarios
    - Power output profile matches qualitatively
    - Minor adjustments necessary in control parameters to get excellent match between the two

- Future Work
  - Installation of GBS in St. Mary's and model validation
    - Procurement of 1 MW unit underway
    - System behavior will be used to validate model

  - Extension of models/lessons learned from islanded to rural and other systems
    - Identify specific power quality issues on member distribution systems
    - Narrow issues to those that can be mitigated with GBS incorporation