



Alaska High Variable Renewable Penetration Microgrids

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Adapted from:

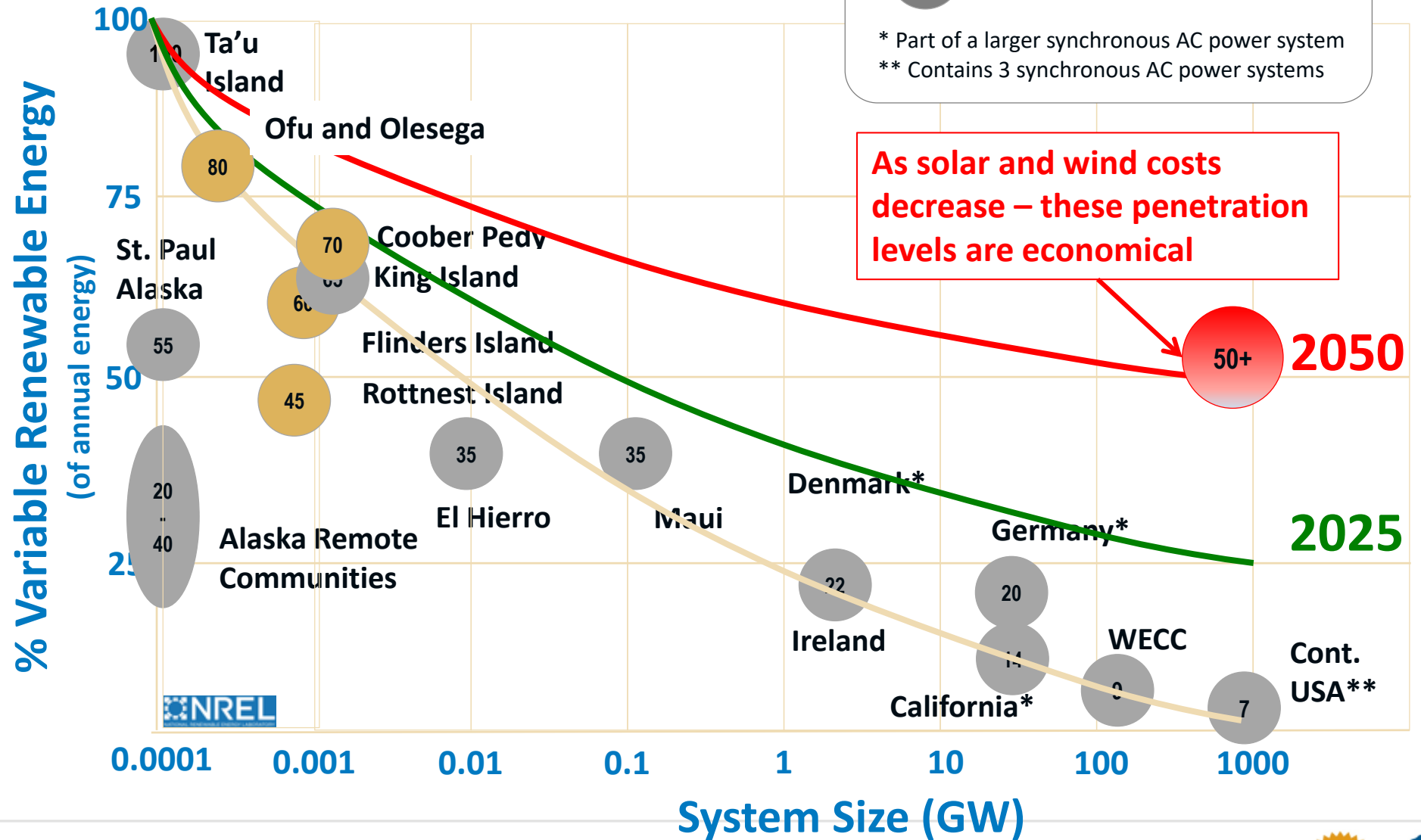
Ben Kroposki, NREL

References:

B. Kroposki, et. al.,
"Achieving a 100% Renewable Grid," *IEEE Power and Energy Magazine*, Mar/Apr 2017, pp 61-73.

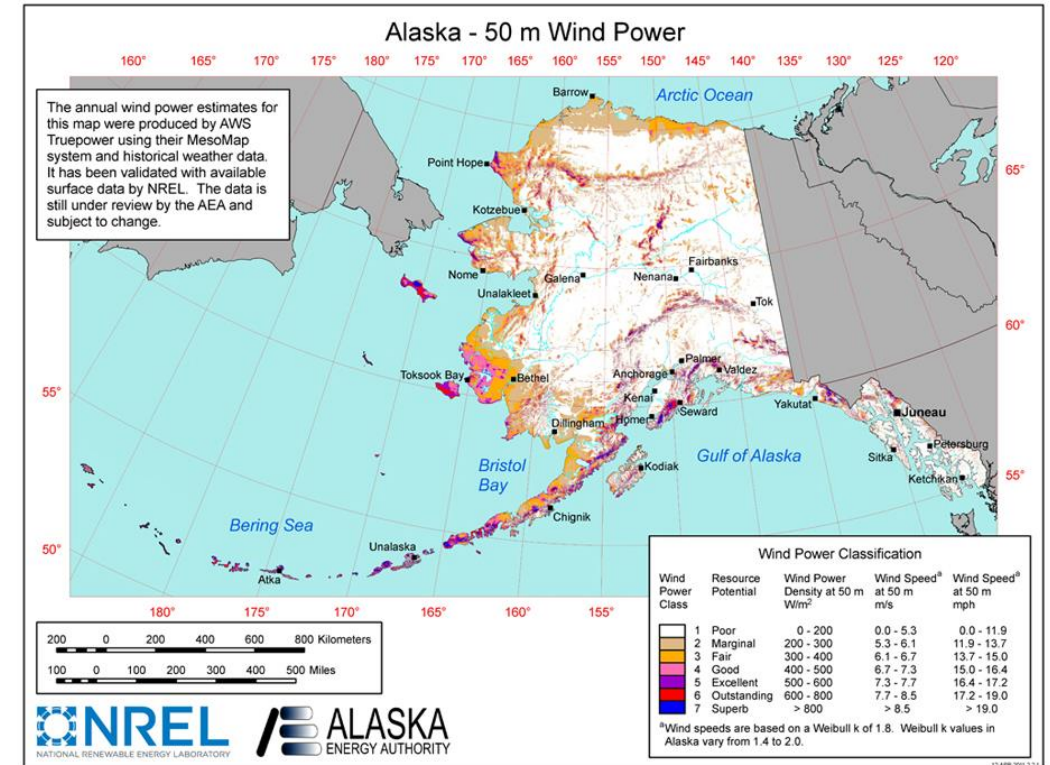
B. Kroposki,
"Integrating high levels of variable renewable energy into electric power systems," *Journal of Modern Power Systems and Clean Energy*, Oct 2017, pp 831-837.

Published Concept Paper in 2016:
Achieving a 100% Renewable Grid
<http://ieeexplore.ieee.org/document/7866938/>



Alaska wind-diesel systems

- ~ 2 dozen wind-diesel systems
 - 18 kW - 3 MW average load
 - ~6 30-40% average wind penetration
- Three operational diesel-off systems
 - St. Paul Poss Camp (1999)
 - 70 kW average load
 - 34% (55%) average penetration
 - Synchronous condenser
 - Thermal storage
 - Kongiganak and Kwigillingok (2017/20)
 - 117 / 150 kW average load
 - 29% (before BESS - now?) / 34% avg. pen.
 - Li-ion BESS with Inverter
 - Electric thermal stoves - distributed heat



Some history

- Metlakatla (1997, 2008)
 - 3.5 MW peak load at time of installation (sawmill)
 - 5 MW hydro, 3.3 MW diesel now standby only
 - 1 MW / 1.4 MWh Lead Acid battery
 - Frequency responsive regulating reserve
- Kotzebue (1997, 2105)
 - 2 MW average load / 3 MW peak load
 - 2.94 MW wind, 20% average penetration, 80-90% max instantaneous penetration
 - 1.25 MW / 950 kWh lithium ion BESS
 - Frequency responsive reserve - wind plant support
- Wales (2002 - Non-operational)
 - 70% penetration (design)
 - Ni-CAD BESS with rotary converter
 - Electric boiler
 - Lessons learned



Challenges and opportunities

- Variable and uncertain resource
 - Regulating reserve
 - Contingency reserve
- Converter-dominated power systems
 - Stability
 - Low to zero inertia
 - Frequency is no longer a fundamental indicator of power balance
 - Converter control algorithms play leading role
 - Fault identification and clearing, protection coordination
 - Motor loads
 - Black start
 - Transient and dynamic modeling
- Replacing lost heat to heat recovery loads
- Emissions regulations
- DC inerties



ACEP PSI Lab

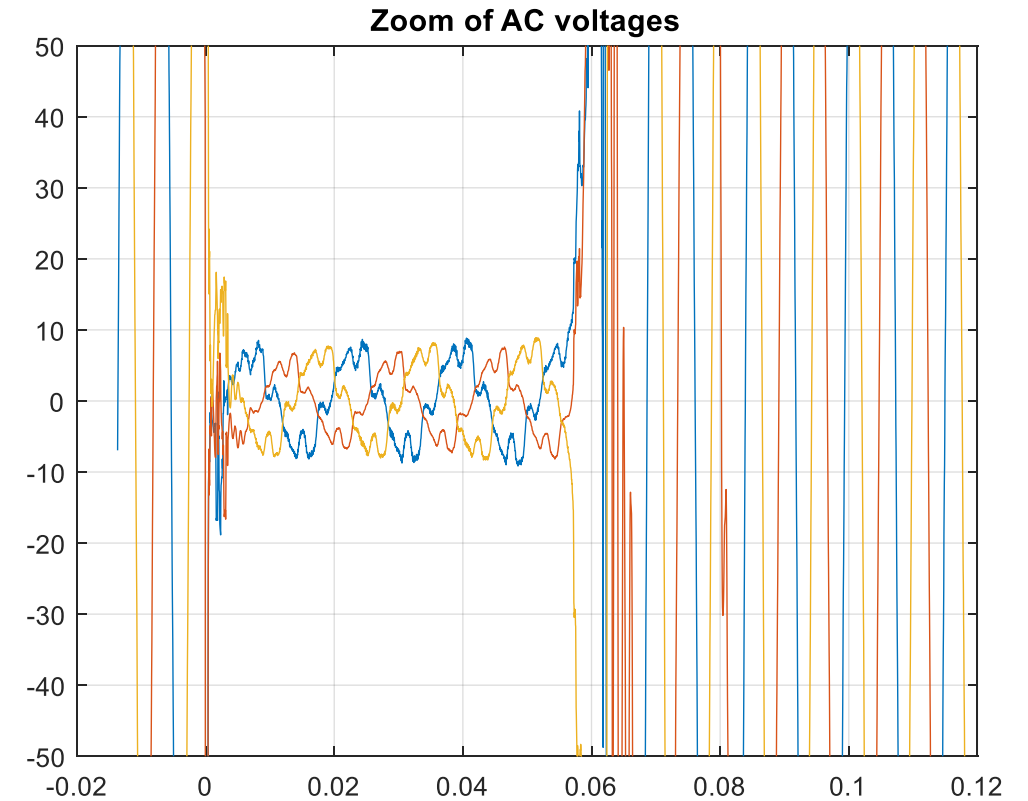
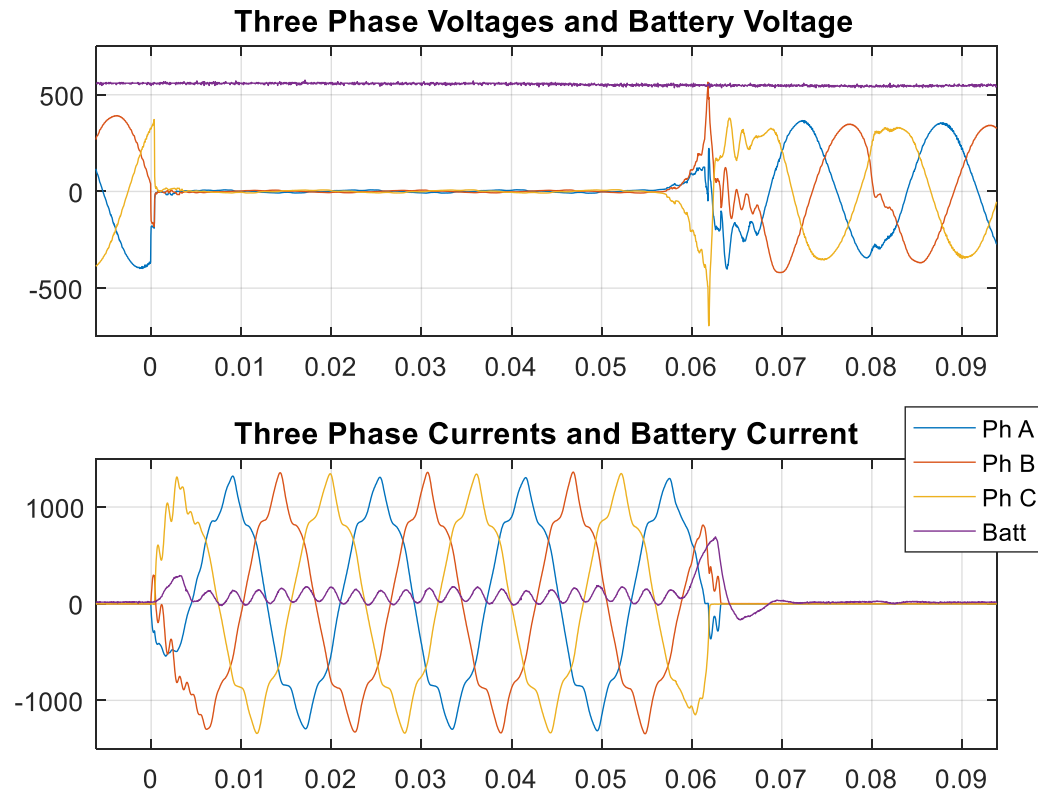
- Diesel generators
 - 320 kW Caterpillar C-15, Woodward easYgen
 - 125 kW Detroit Diesel, Woodward easYgen
- 100 kW PV simulator
- 100 kW wind turbine simulator
- Battery energy storage system
 - 600 kW / 270 kWh lead-acid battery
 - 313 kVA ABB PCS100 Inverter
- Load banks
 - Two 250 kW / 188 kVAR RL load banks
 - 5 kW / 3.75 kVAR steps
 - 55 kW resistive load bank
- Fault emulator
 - 3-phase, 480 V, up to 10 kA faults
 - Faults: 3-phase, single l-l, single l-g
- Future: line impedance simulation



Three-phase fault emulator

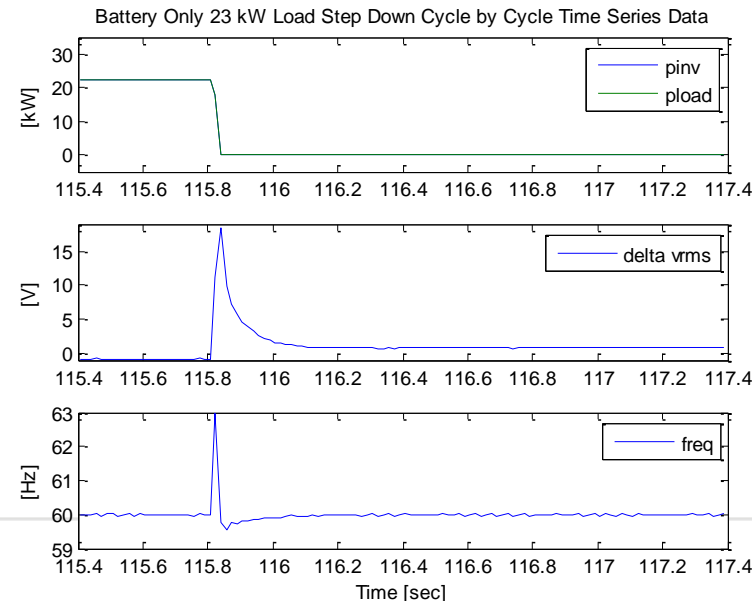
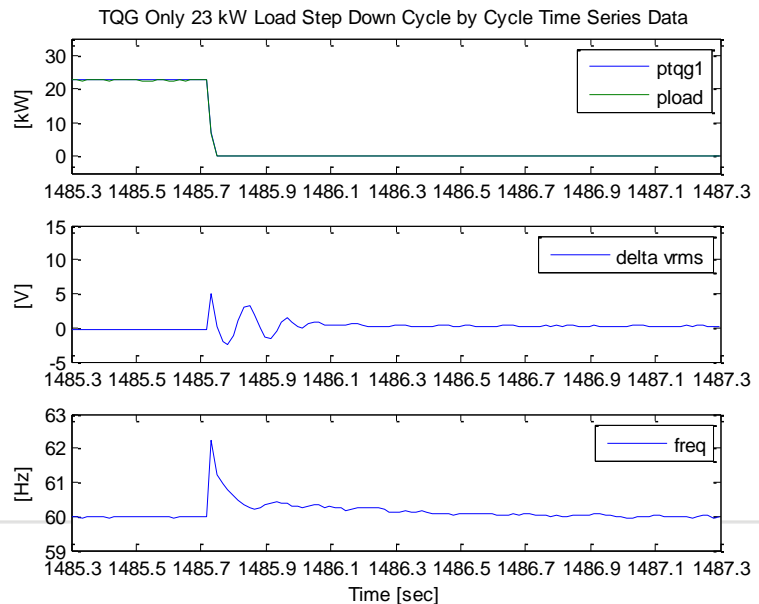
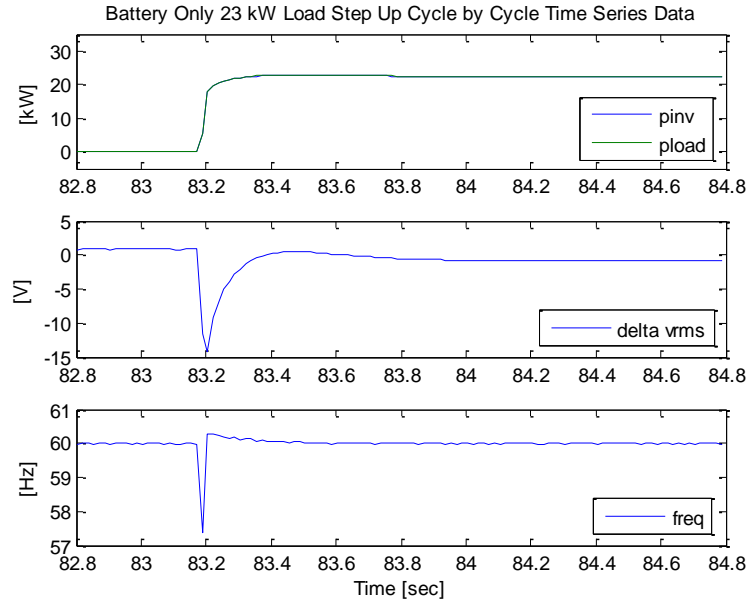
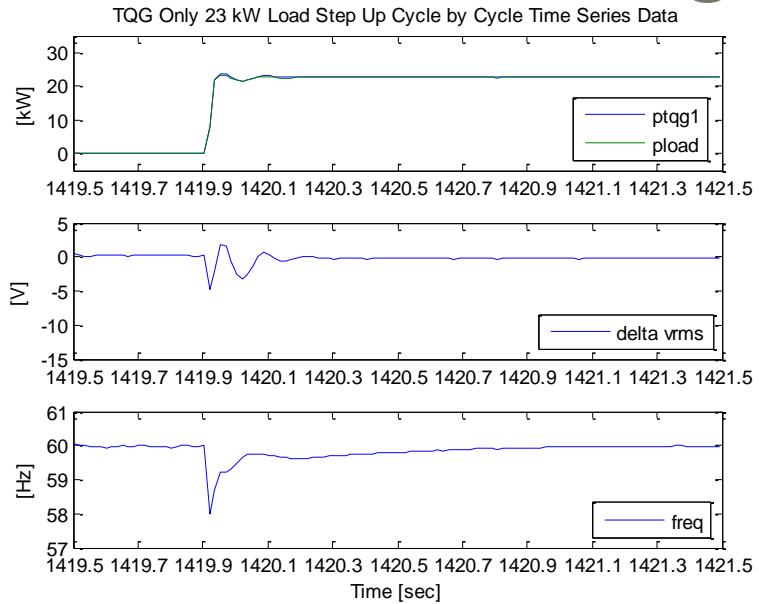


Initial fault tests: Bolted 3-ph fault with BESS, 40 A type K fuse



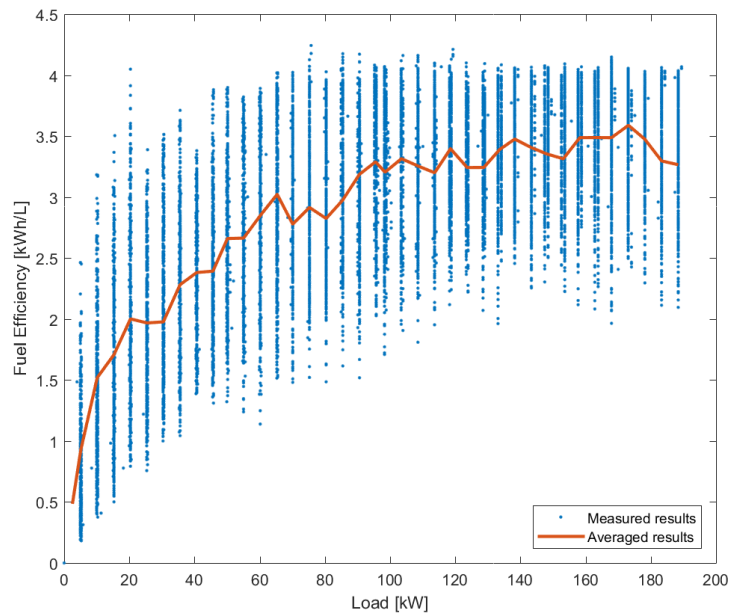
Characterizing system dynamics:

Load Step Response Example

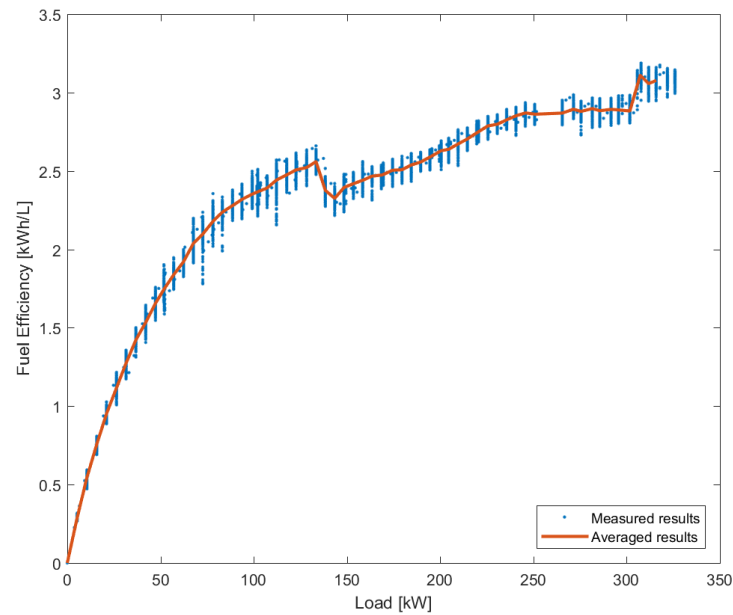


Effect of ramp rate on diesel fuel efficiency

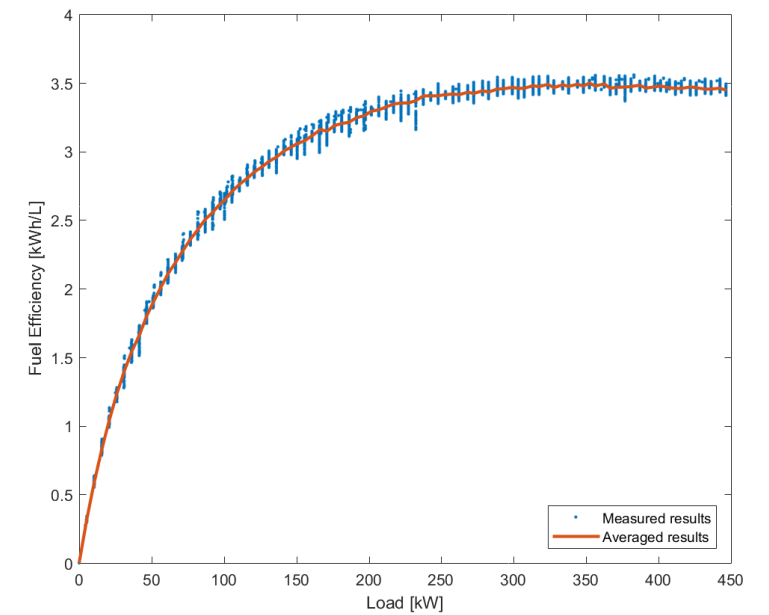
Steady state fuel curves



190 kW
Tier 4



320 kW
Tier 3



457 kW
Tier 2



Thank you!

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