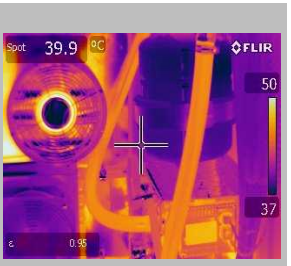

Sandia National Laboratories

Exceptional service in the national interest

Forward Operating Base Microgrid, Evaluation and Testing of Energy Storage Systems

SAND2013-9033C

10/21/2013

David Rose, Ben Schenkman, Dan Borneo

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U.S. DEPARTMENT OF ENERGY NNSA

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Forward Operating Base (FOB)

- A place for soldiers to live in the middle of nowhere
  - Sleeping
  - Cooking/Eating
  - Cleaning
  - Calling Home
- Resources
  - Food
  - Water
  - Energy
    - Diesel Fuel

FOBs
Resupplied by Convoy

Forward Operating Base Energy

Sandia National Laboratories

Cost

Up to $400/gal

(Ref: Bemer 2010)

Casualties

1 in every 46 convoys

(Ref: Ramdass 2010)

Base Camp Integration Laboratory (BCIL)

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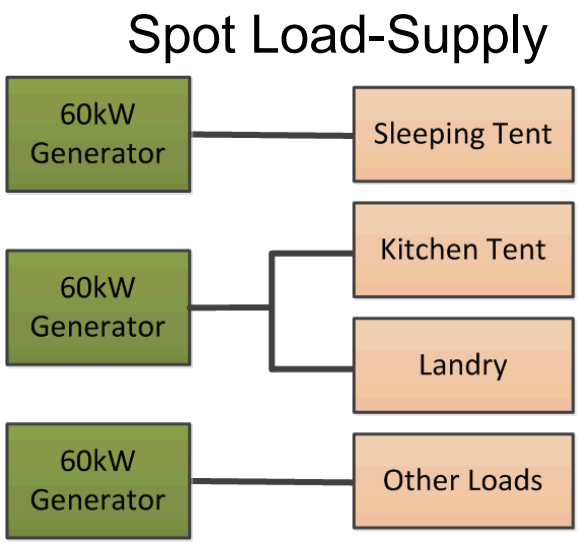
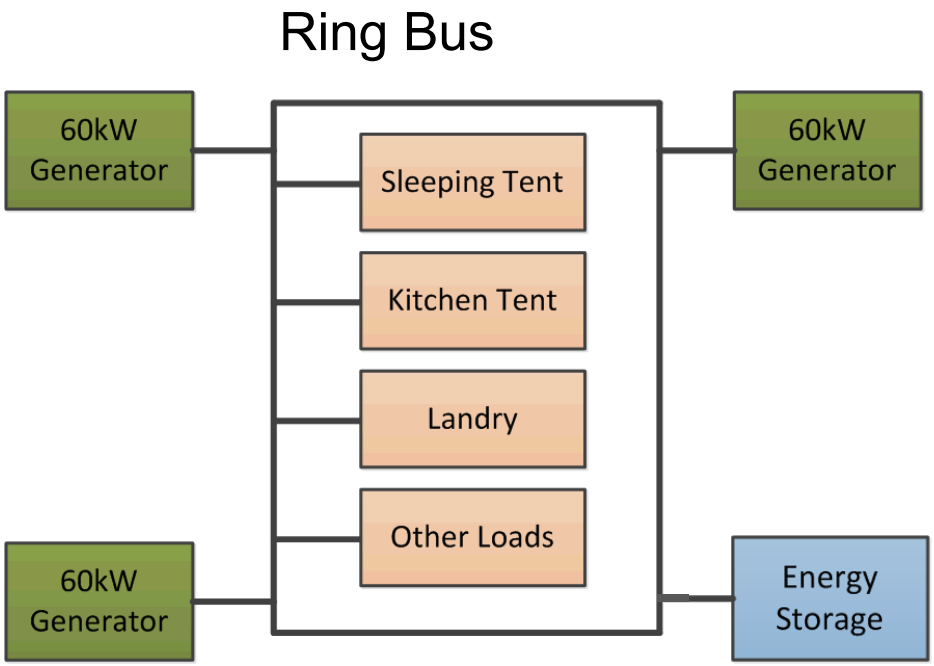
- Forward Operating Base Resource Efficiency
  - Water, Food, Waste, Energy
- Reducing the Need to Resupply
  - Convoy Reduction

Microgrid Electrical One-Line

- Baseline Camp



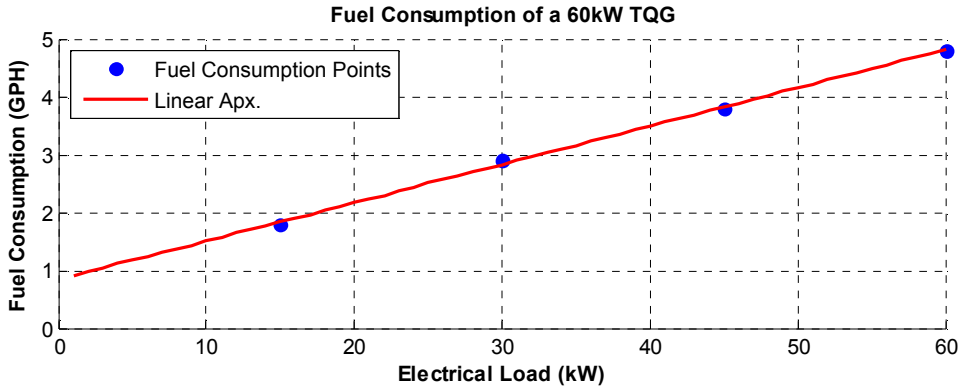
- Improved Camp

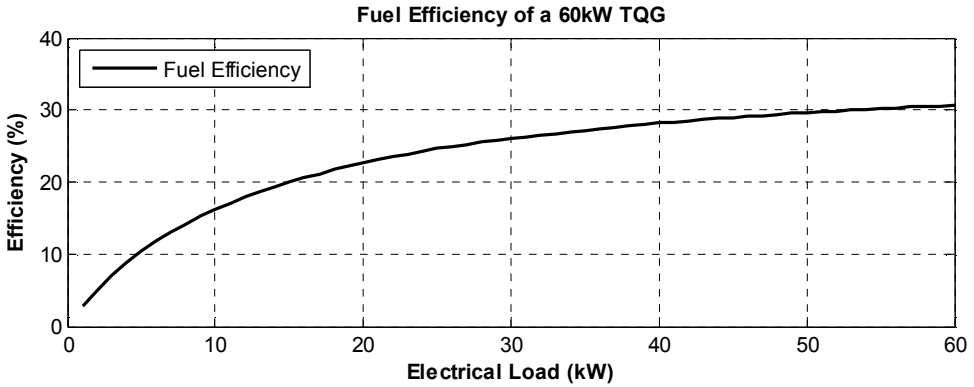


- Connecting all sources to all loads can optimize fuel use
- 20%-30% fuel savings
- Can Energy Storage do Better?

Tactical Quiet Generators (TQGs)

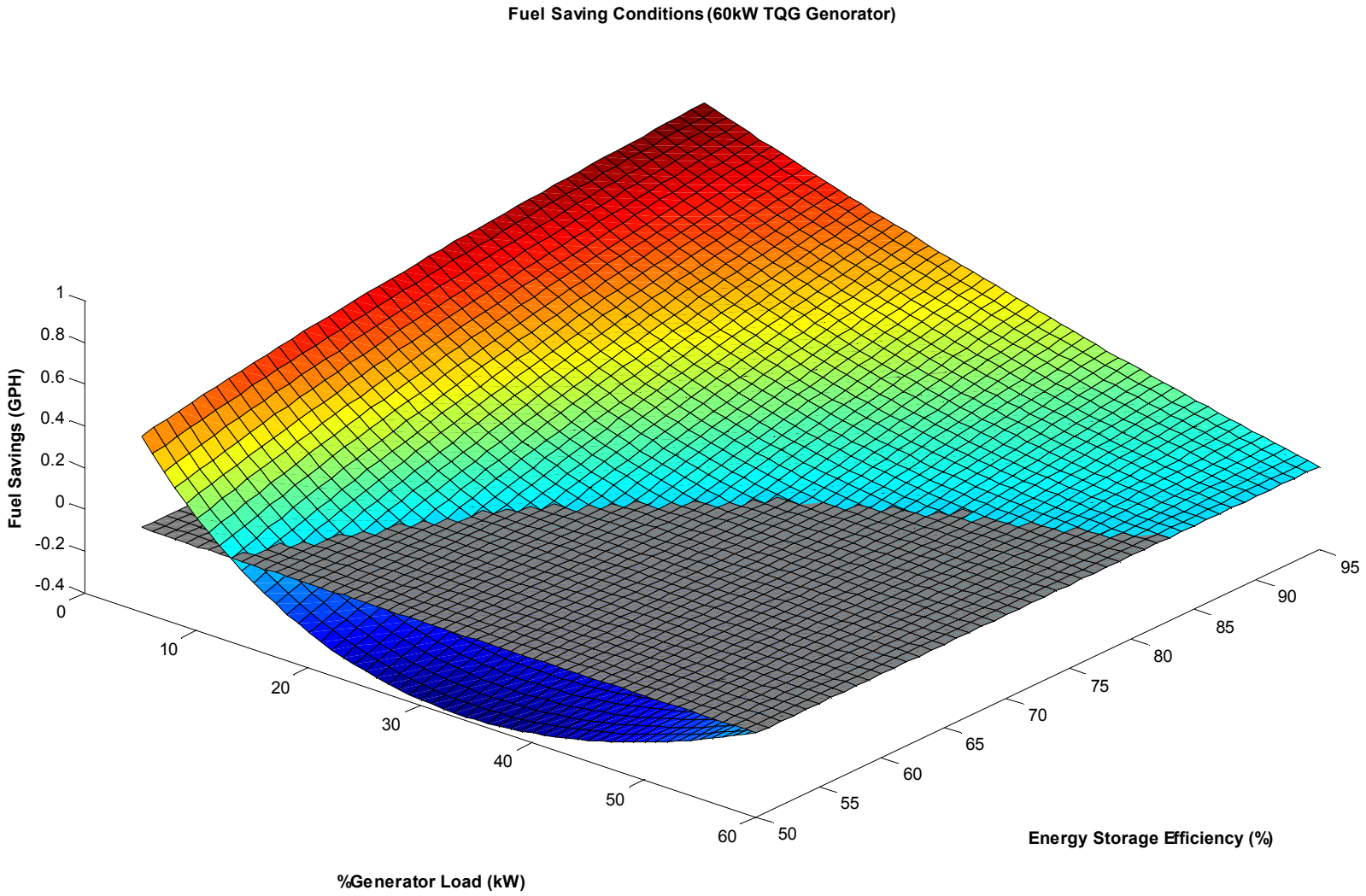
- More efficient at higher load
- Wet-Stack below ~30% load
- Require ~20% for spinning reserve when sharing load
- Ramp Rate Limitations



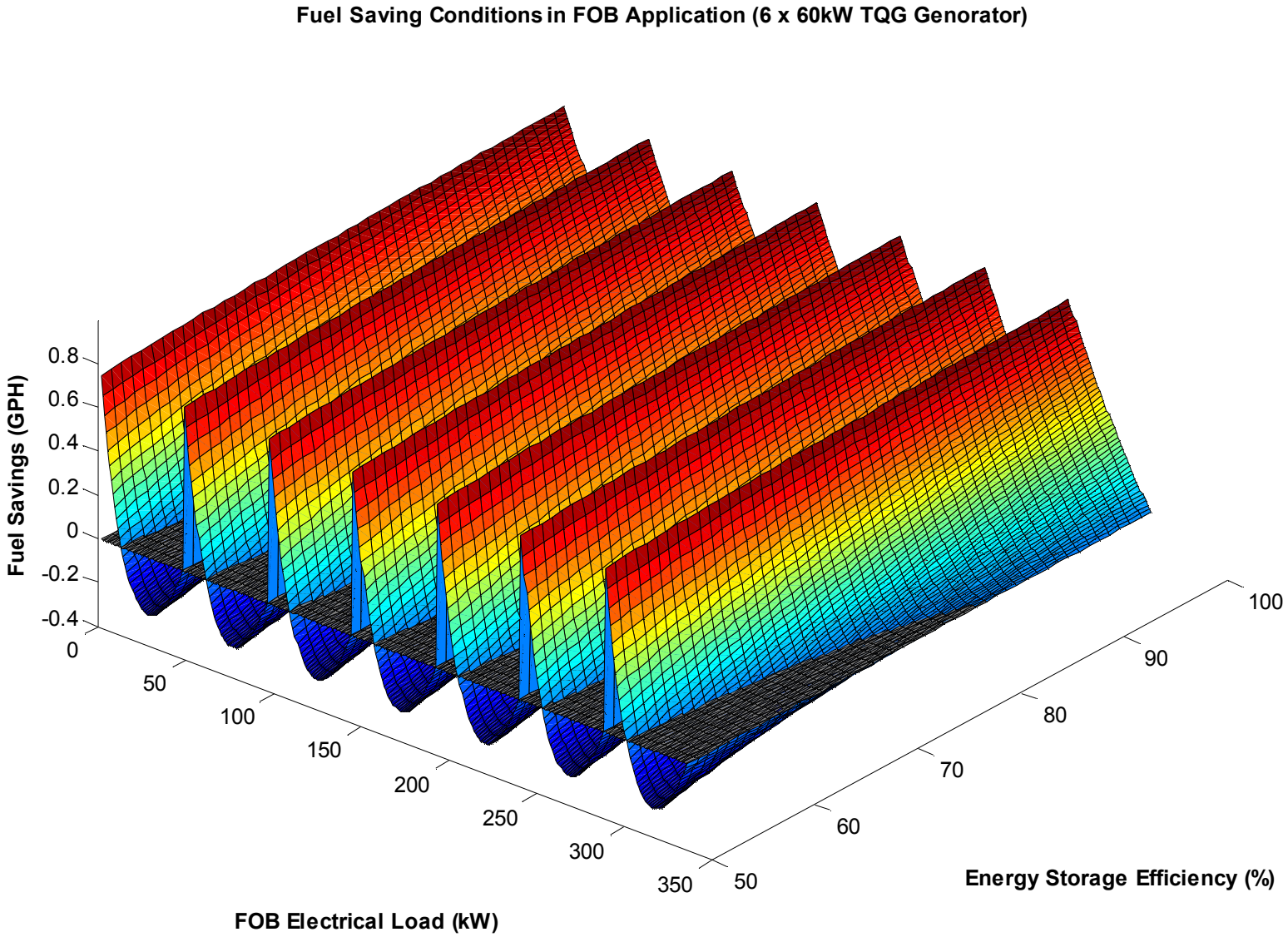


- When a generator is lightly loaded
  - Energy storage can reduce runtime to improve efficiency

Generator Fuel Savings



Microgrid Generator Fuel Savings



Energy Storage Test Pad (ESTP)

- Scalable from 1 KW to 1 MW, 480 VAC, 3 phase.
- Enables detailed independent analysis of system performance and safety
- Integrated with Distributed Energy Technologies Lab (DETL) and can analyze advanced inverter functionality up to 200kW
- Grid simulation allows for precisely controlled changes in voltage, frequency, phase imbalance, and power quality
- Analysis duration is flexible to accommodate customizable testing scope.

Milspray Military Technologies

Milspray Scorpion: 15kW - 79kWh - VRLA Batteries

Princeton Power Systems

Prototype ESS: 100kW - 82kWh – Li-Ion Batteries

Raytheon/KTech

RK30 ESS: 30kW - 120kWh - Zinc Bromide Flow Batteries

GS Battery and EPC Power

HES RESCU: 60kW - 106kWh - VRLA Gel-Type Batteries

Performance Analysis

Developed Procedures to Evaluate System Performance

- Capacity
  - An analysis of maximum system energy
- Command Response
  - An analysis of the system's response characteristic to set point changes
- Frequency Response
  - An analysis of the system's response characteristic to frequency changes
- Voltage Response
  - An analysis of the system's response characteristic to voltage changes
- Inverter Characterization
  - An analysis of inverter power quality and efficiency

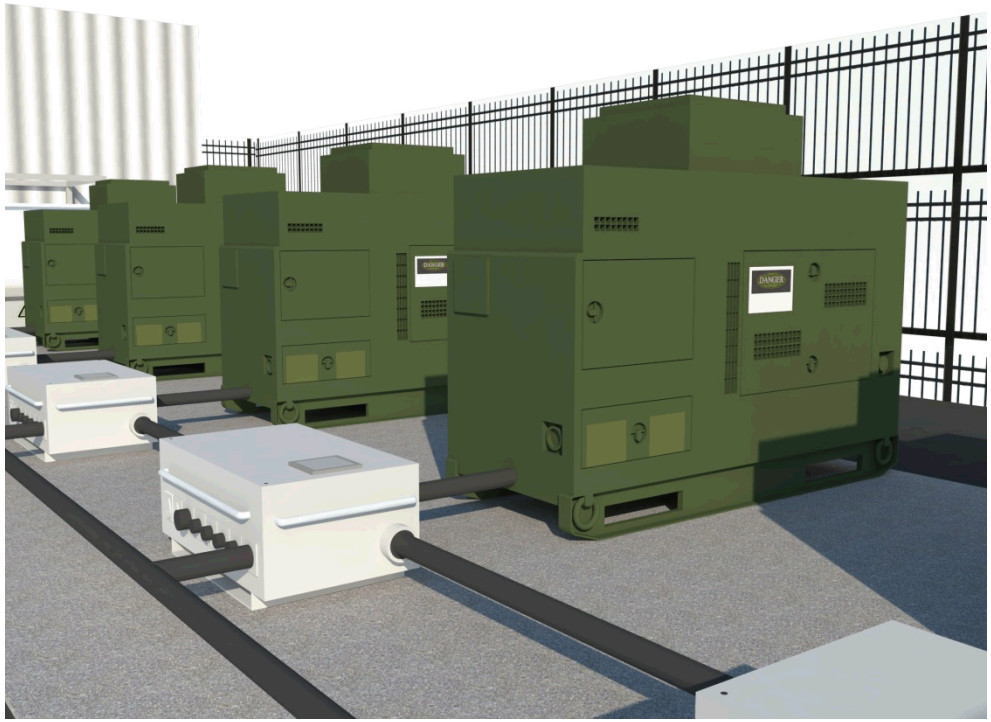
Impact

Design changes as a result of testing

- Safety
  - Battery rack shield installed
  - Smoke/heat detector has been installed in the system and wired to the AC and DC safety isolation breakers
  - DC breaker safety shield installed
- Performance
  - Voltage response implemented
  - The Delta to Wye transformer has been removed to increase performance and reduce weight
  - Inverter stability window had to be expanded
  - Different inverters will be installed in future designs
  - Reprogramed Frequency Response PLC for more robust operation

Future Tasks

- Integration of Energy Storage and TQGs into Sandia ESTP Microgrid
- Potential Performance Metrics
  - Fuel Savings
  - Load Balancing
  - Power Quality
  - Renewable Integration
  - Reliability



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