Limits and Opportunities for improvements in hybrid power systems.

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September 2014

Abstract

A method is presented for analyzing hybrid power systems and deriving theoretical limits to renewable energy penetration under given control paradigms.

Overview

- What:
  1. **Wind/PV/Diesel**/Battery/Flywheel Hybrid Power Systems.
  2. In the 100kW to 2MW total load range.
  3. Formal Model that gives Limits, Scaling Laws, Test Environment.
- Why:
  1. There are too many suboptimal hybrid-diesel systems.
  2. There are too many fast-talking salesmen that promise too much.
  3. This has not been formalized, as far as we know.
- Who:
  1. Experts: to know what you can/cannot do. “A perfect ... under assumptions ... can only do ...”.
  2. Non-experts: to know what the experts can do.

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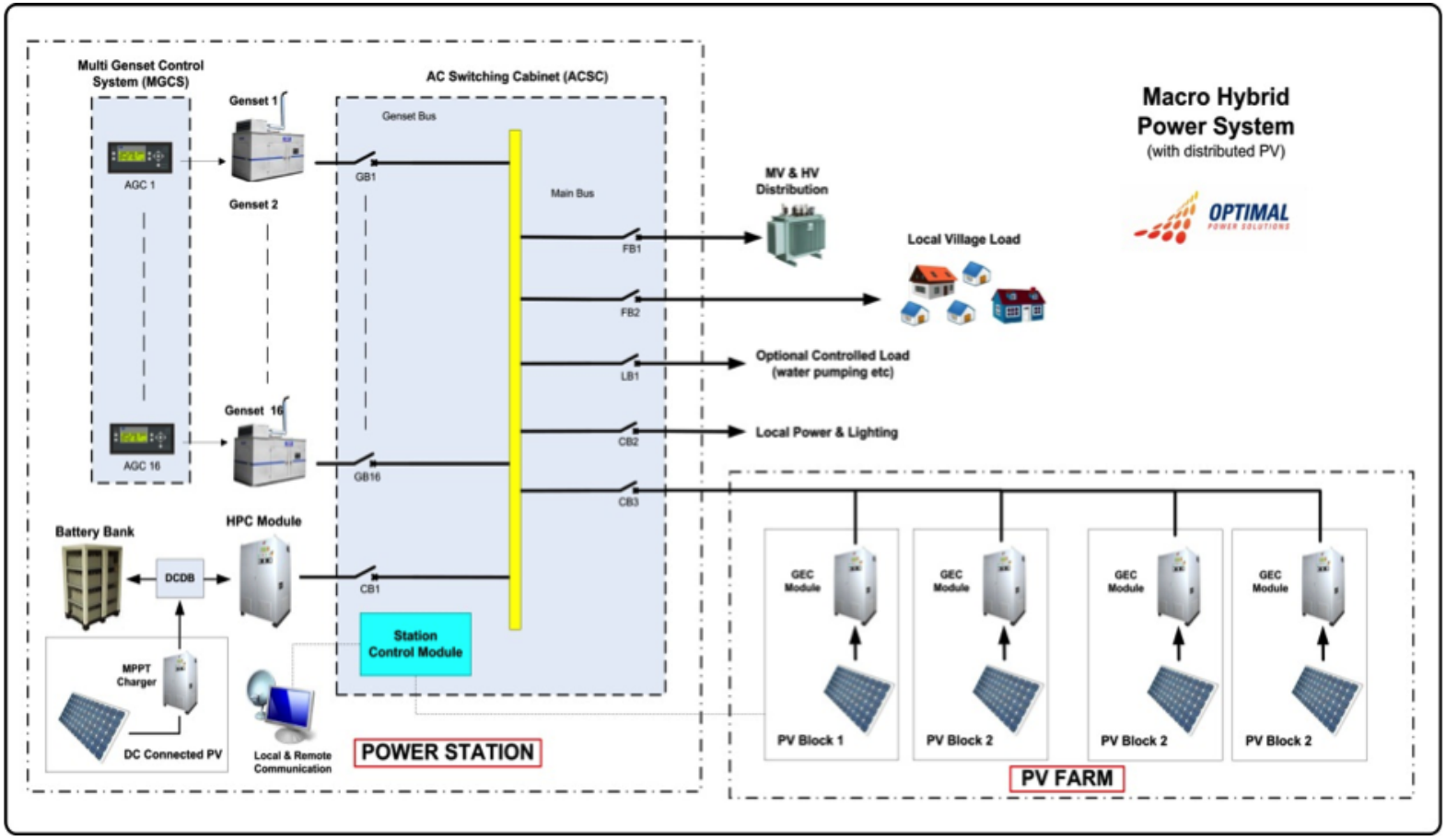
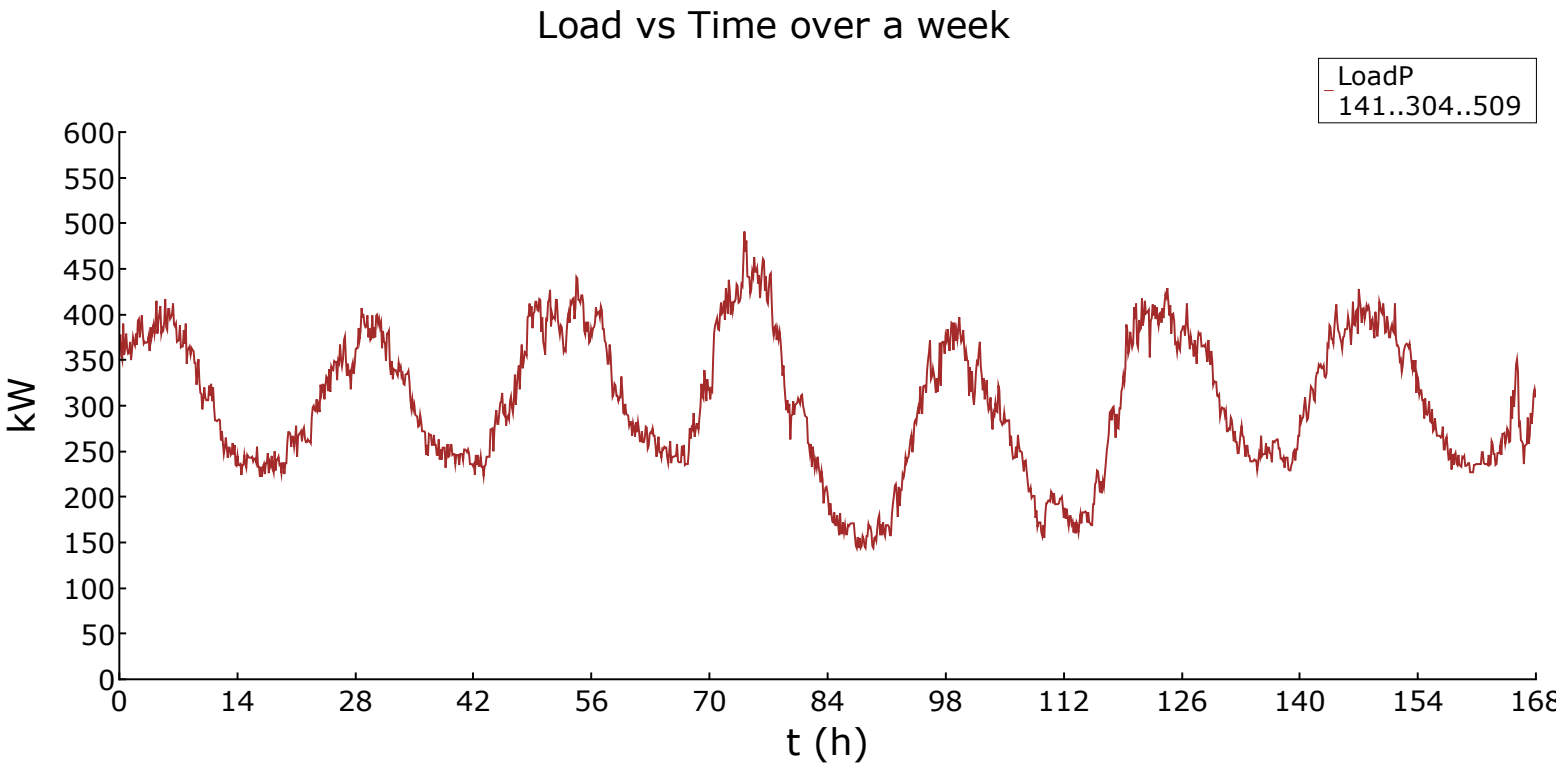
  3. Diminished returns.

Typical System

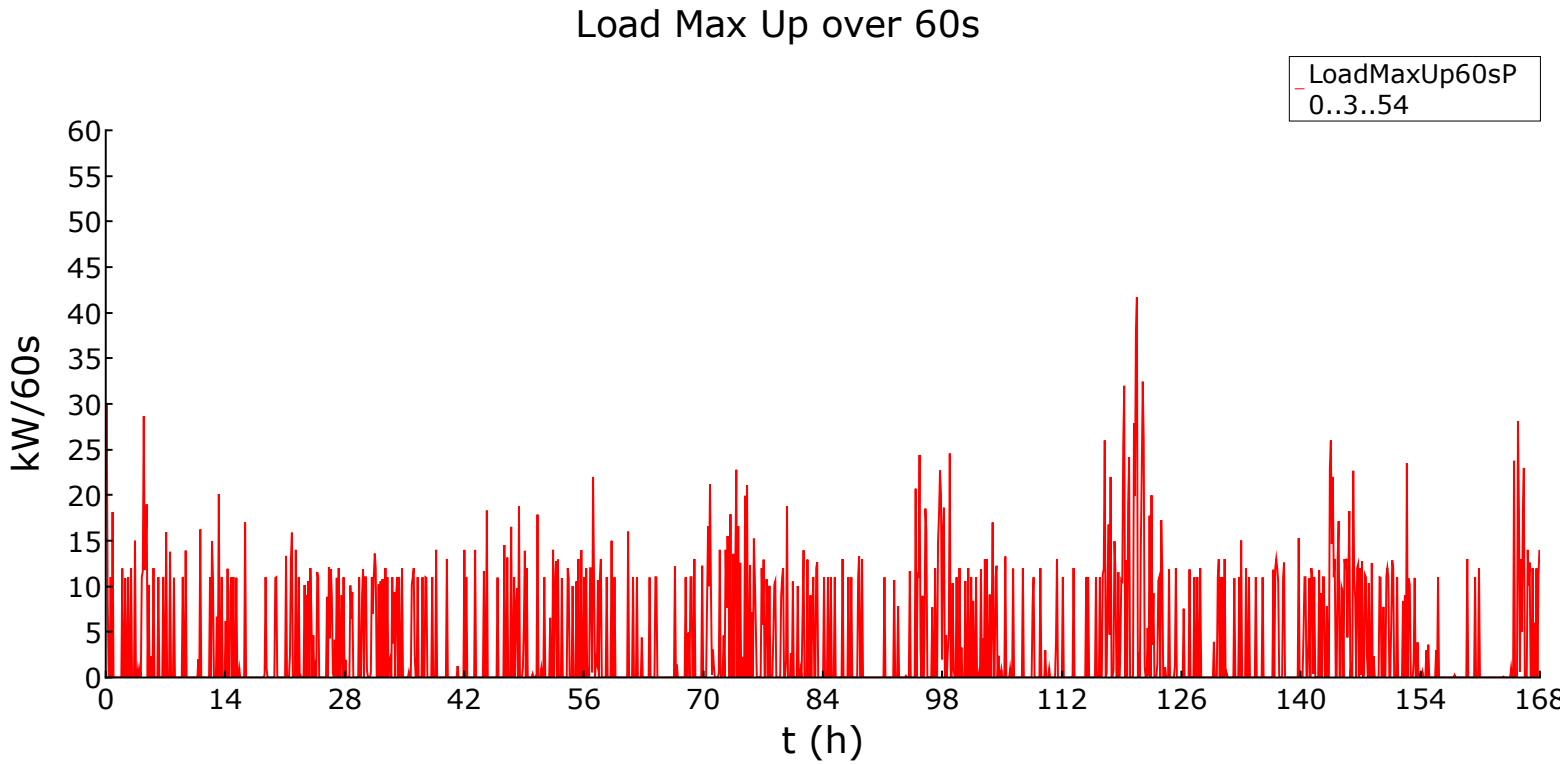


Load vs time



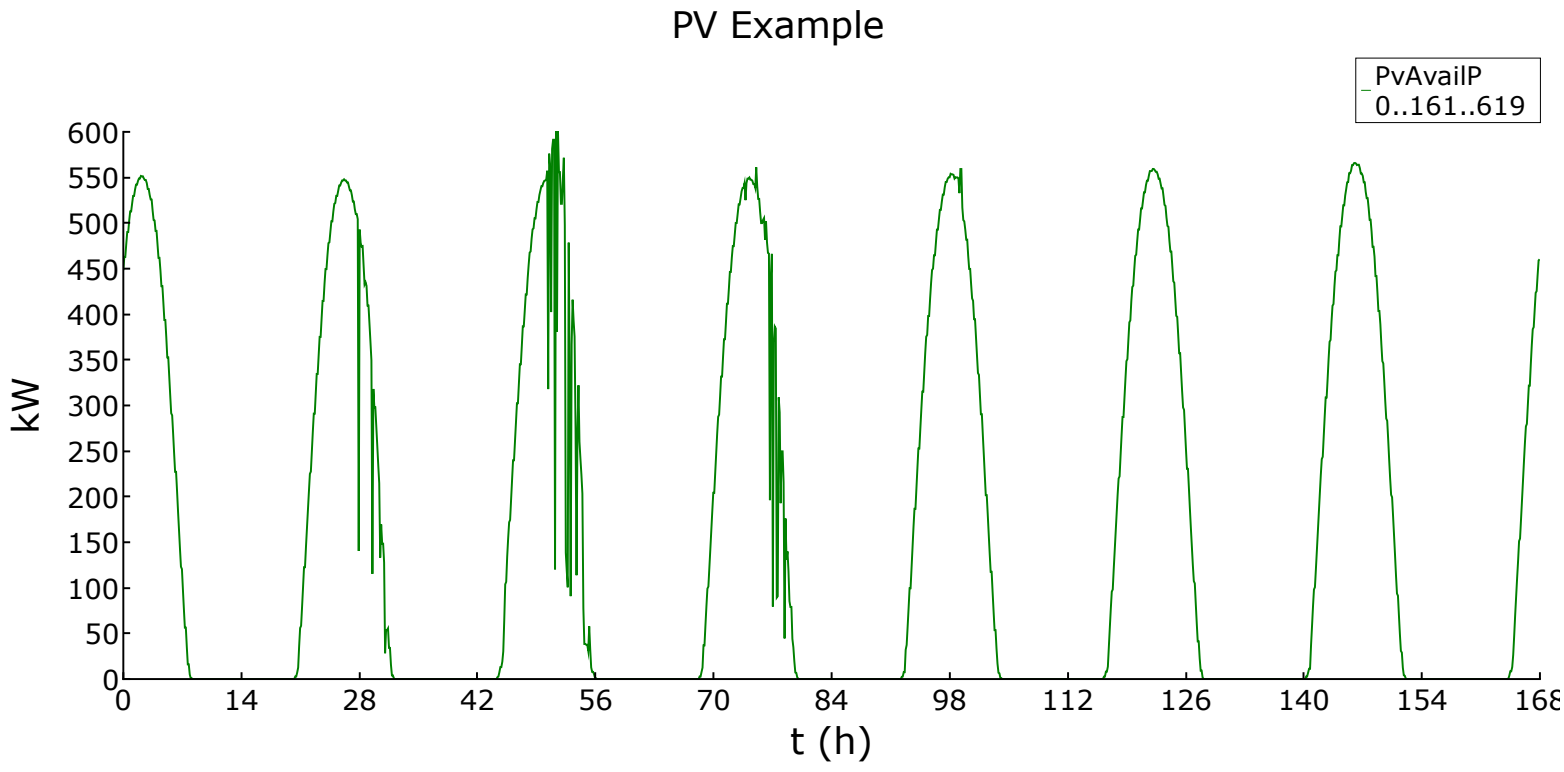
System load varies over the day and week.

Load vs time



Since diesels start times are typically 60s the traditional approach of keeping around 40kW of Spinning Reserve is close to optimal, except for renewables or storage.

Renewable Variability



Typically for PV in this range we might get a drop of 80% within 6-12s (or up to 40kW/s for a 300kW PV array).

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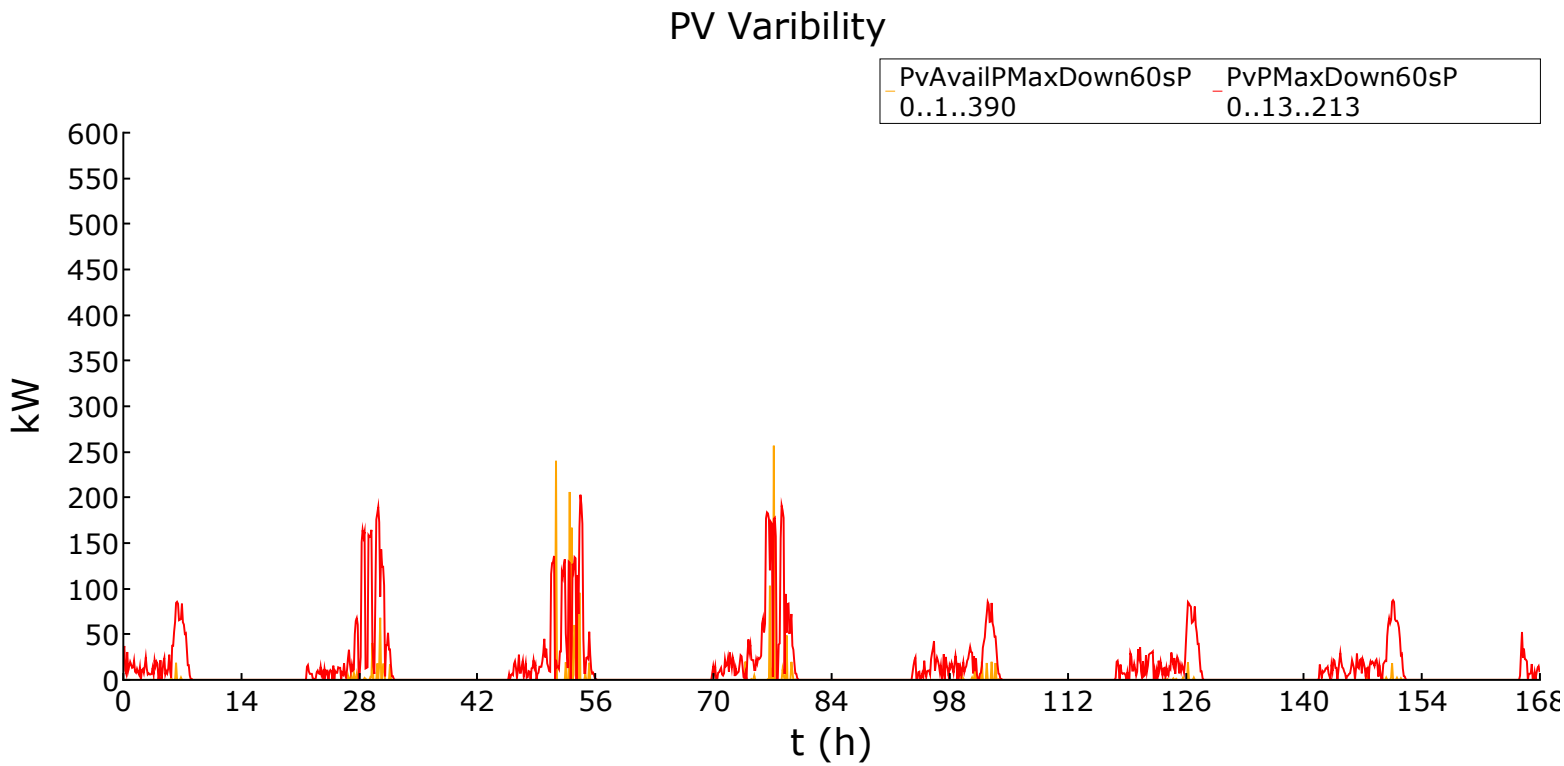

- Output variability over 60s is much higher than spinning reserve.

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  2. Oversizing Diesels, RE generation, and auxiliary equipment increases costs.

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No Awareness of RE Generation

The diesel powerhouse control system has no operational information about RE generation: this is typical with small distributed PV. When there is lots of it, this can be a real problem.

- The RE generation acts like a negative load.
- Worst-case: Diesel powerhouse has to increase fixed spinning reserve as load variations appear greater.

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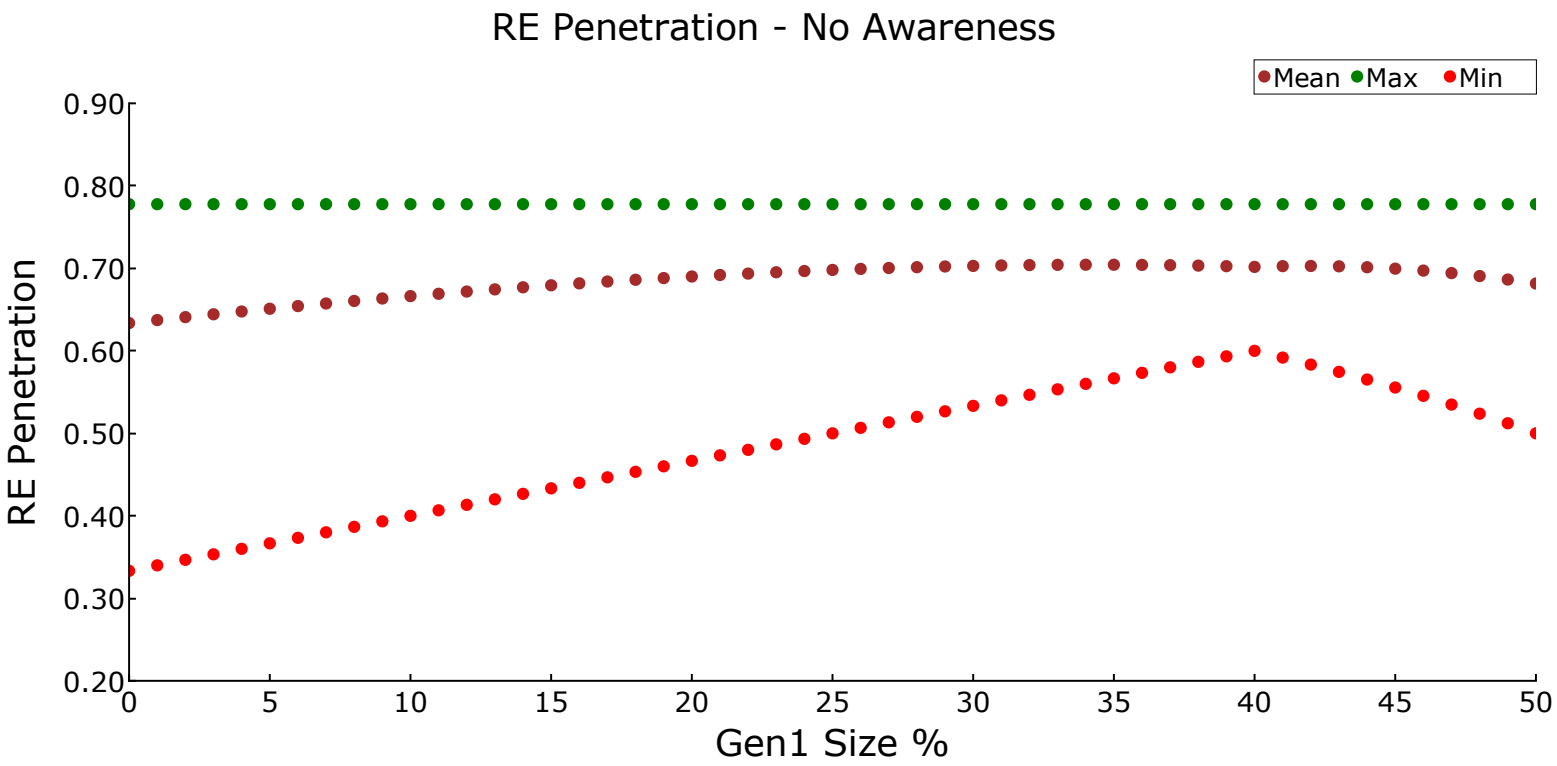

- Mean penetration, even in such a 'dumb' system can be astonishingly high (theoretically).
- There is a slight optimum for generator sizing, with the two units being not quite the same size.

Awareness, but no control

The diesel powerhouse control system has real-time data regarding the output of the RE generation: this is found with medium sized (compared to total system size) third-party owned wind turbines and PV arrays.

- RE still acts as negative load.
- But diesel powerhouse can automatically adjust spinning reserve based on known RE output.

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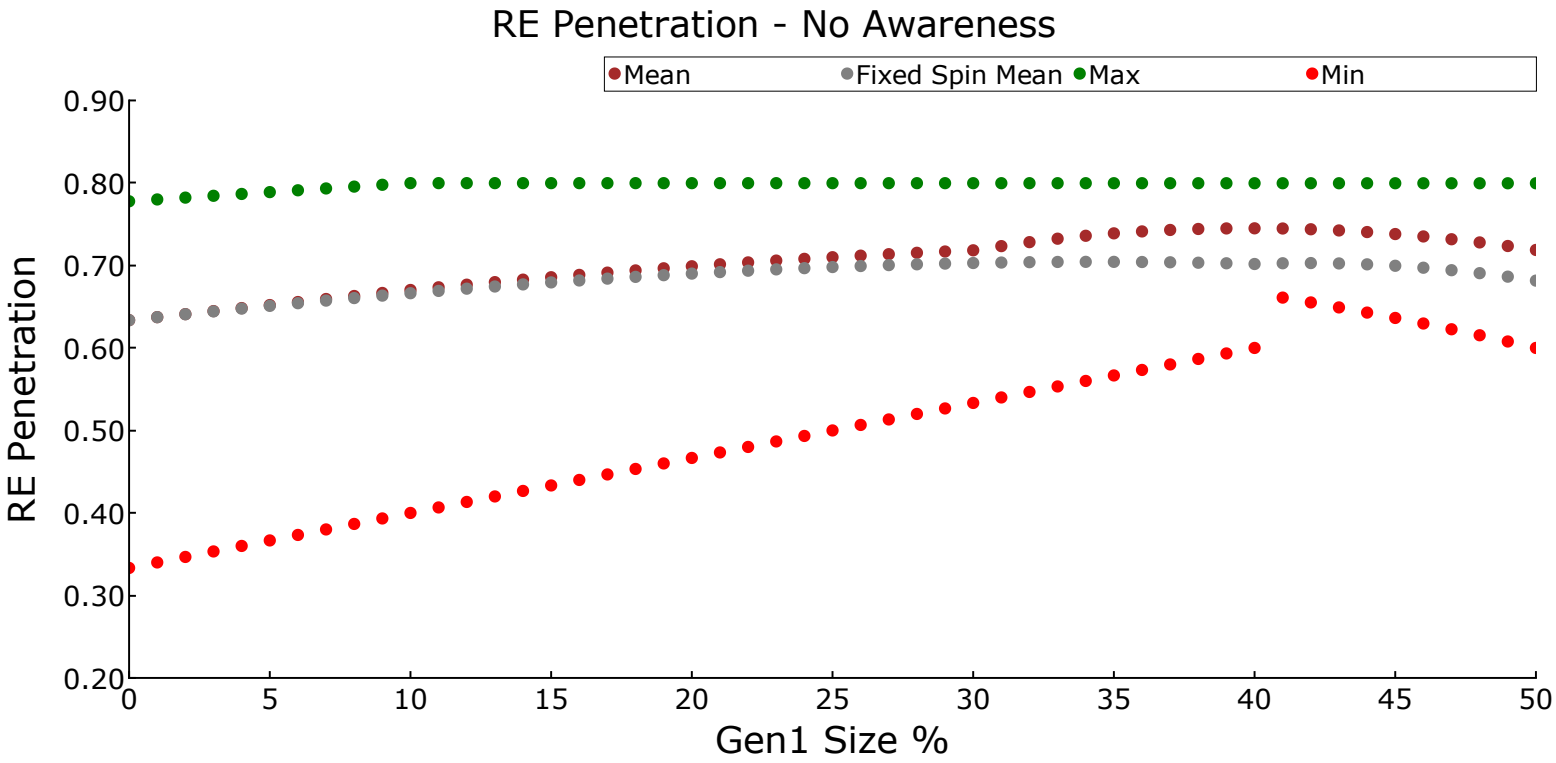
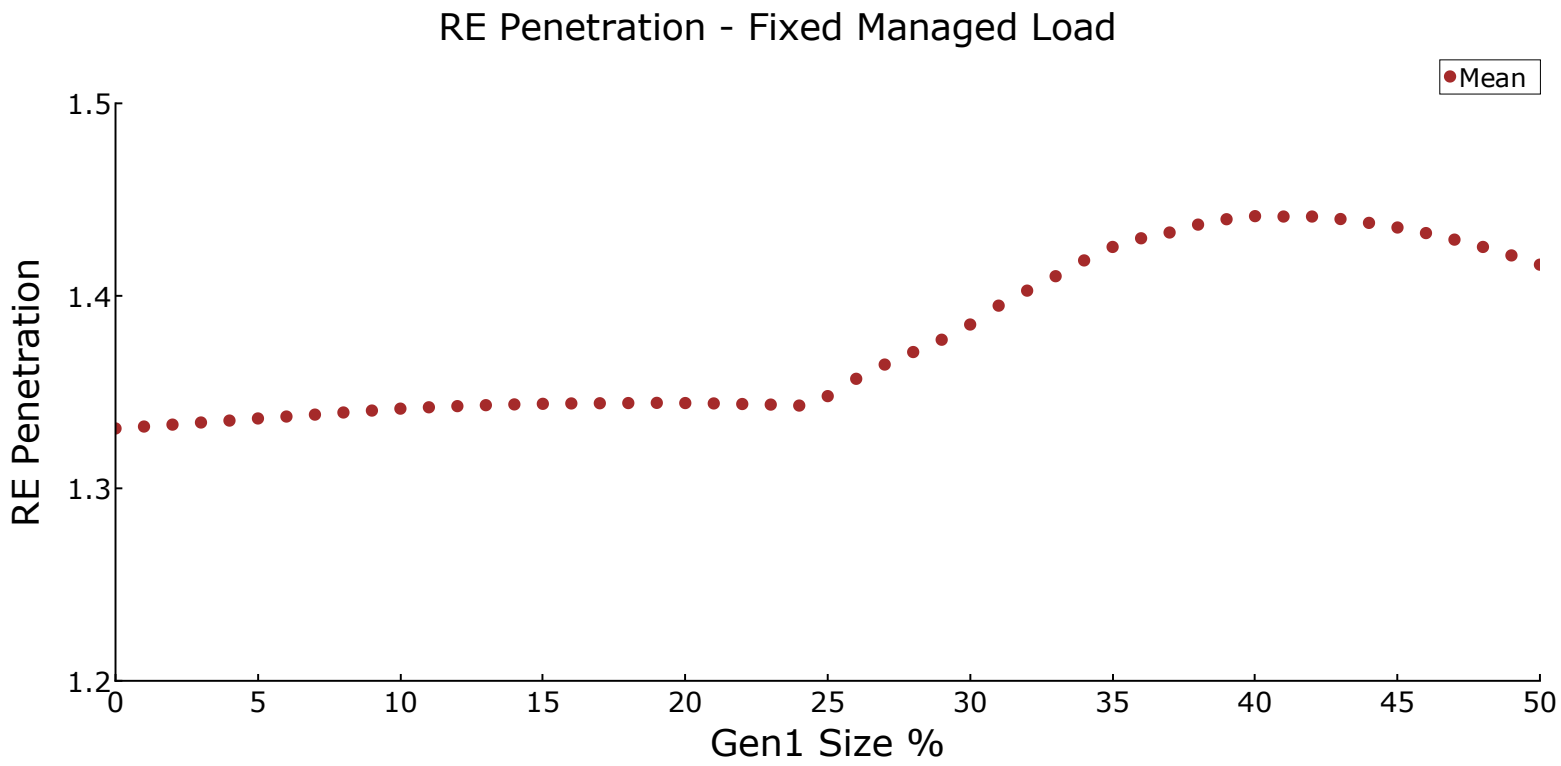


- With variable spinning reserve and at the right generator sizing, the mean penetration is only slightly higher than with fixed spinning reserve (theoretically).
- Great improvement on fuel consumption (not shown), and thus, system efficiency.

RE output control

A supervisory system with access to set points at the RE generation can switch the RE on or off, or turn it up or down. However, at that point, the RE production is not realized. If it is not much that is curtailed, it does not matter. If it is a lot, it diminishes the economic case to a point where it should not be done. We are skipping this.

Negative Spinning Reserve: Load Management 1



- Fixed-size managed load increases potential utilization of RE significantly.

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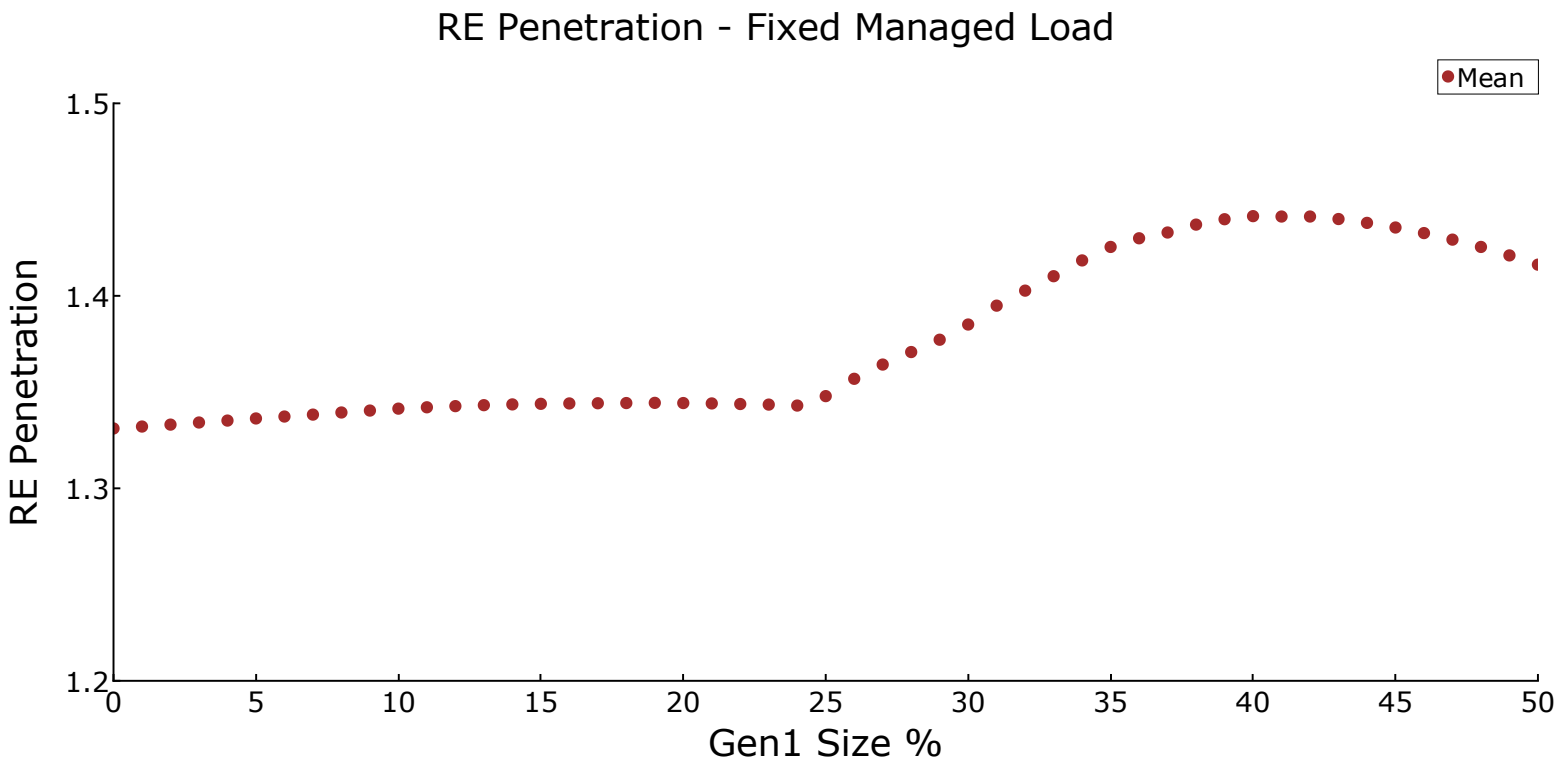
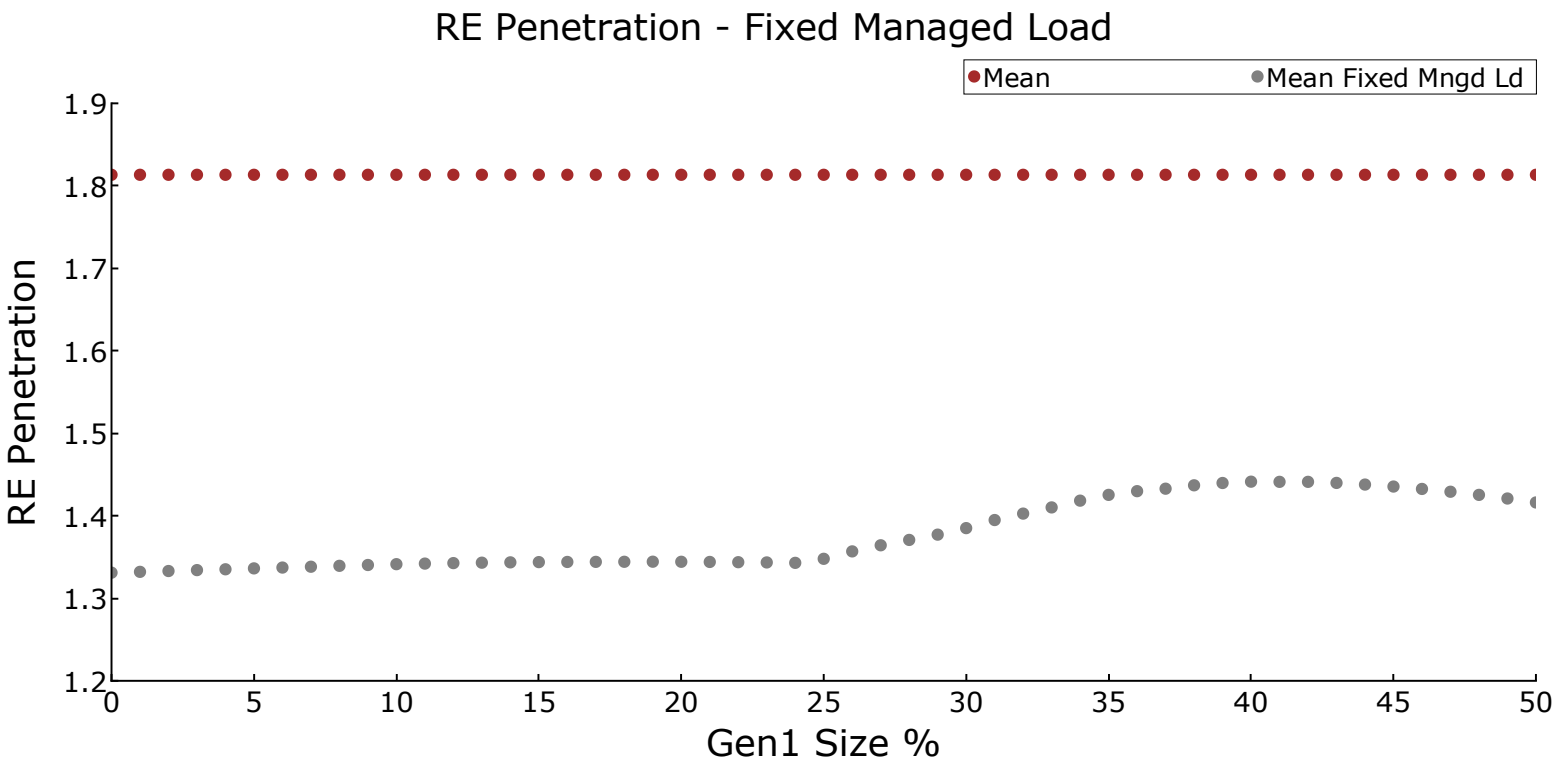


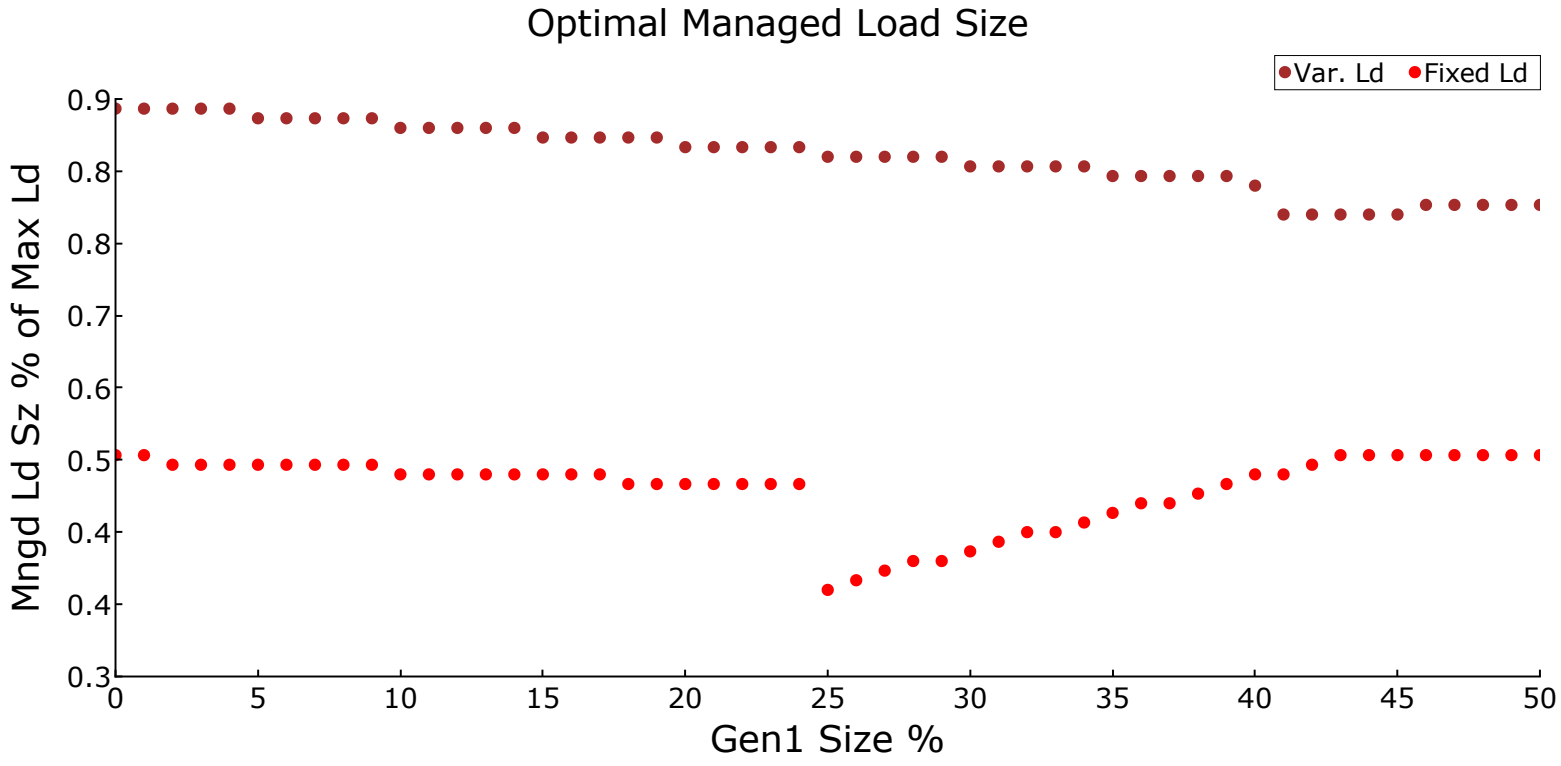
- Fixed-size managed load increases potential utilization of RE significantly.
- Required size of managed load in relation to peak system load is significant.

Negative Spinning Reserve: Load Management 2



- Variable managed load further increases potential utilization of RE.

Negative Spinning Reserve: Load Management 2



- Optimal (smallest) managed load occurs at different generator size combinations for fixed and variable.
- Variable managed load has to be quite large to maximize RE harvest.

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- For optimal RE utilization, utility requires control of portions of the consumer side of the grid (load management).
- Depending on diesels and power quality requirements additional equipment may be required (short-term energy storage).

Outlook and Thanks

- Apply to real world systems - work was motivated by and applied to systems in Australia, and Alaska.
- Contact us at: philip.maker@gmail.com and mmuellerstoffels@alaska.edu.
- This work was partially funded by:
  1. U.S. Department of Energy, Office of Science, EPSCoR Grant
  2. State of Alaska, Legislative Appropriation

Engineers like to solve problems. If there are no problems handily avialable, they will create their own problems. – Scott Adams