BUCHAREST 2018 SYMPOSIUM ON MICROGRIDS
University Politehnica of Bucharest, Romania
2- 6 September 2018

A New Method to Investigate Microgrid Stability Using Parts-per-Billion Voltage Measurements

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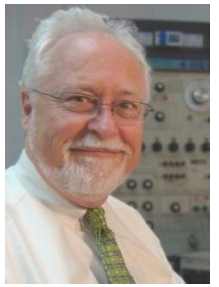
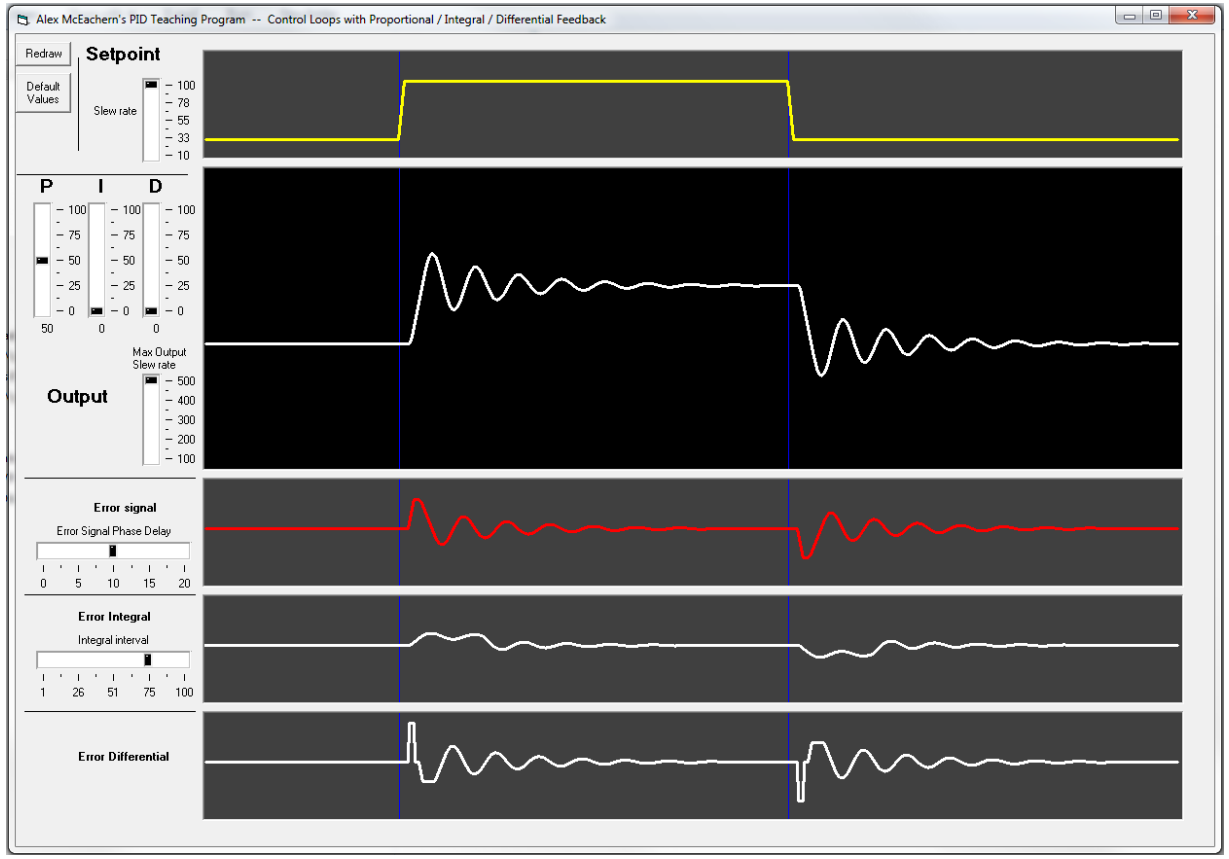


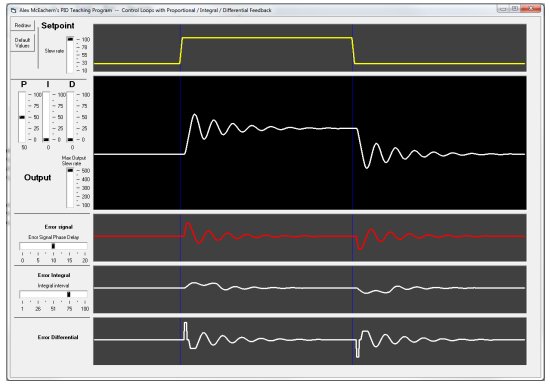
What I mean by “microgrid stability”

- Grid voltage and/or frequency
- Transition from a first steady-state to a different steady-state
  - Oscillation frequency & magnitude
  - Duration of oscillation (“damping”)

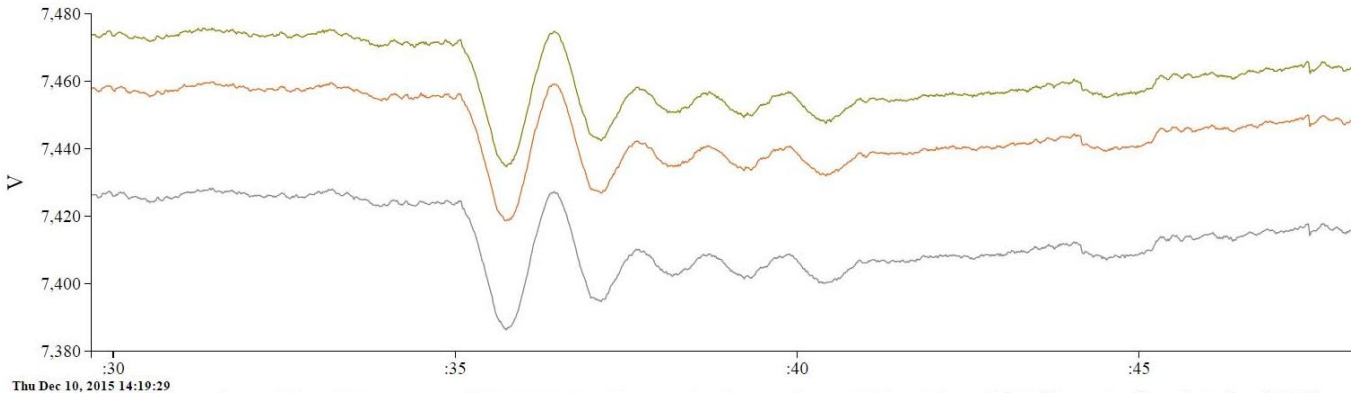


- Why stability matters
  - Usefulness to users
  - Margin for errors
  - Cyber attack vector

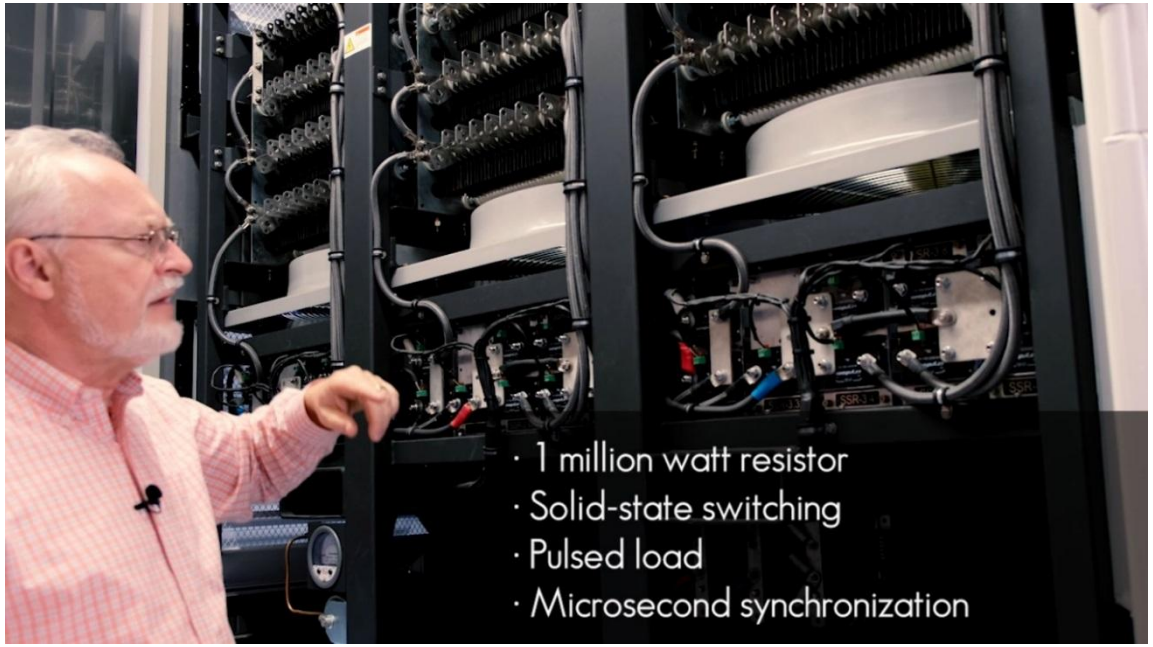
What causes microgrid instability



- PID Control loops designed in isolation
- Intolerant and/or sensitive inverter control algorithms
- Rule-of-thumb generator control loops
- Failure to understand connection net between different control loops



Stability measurement using impulse response

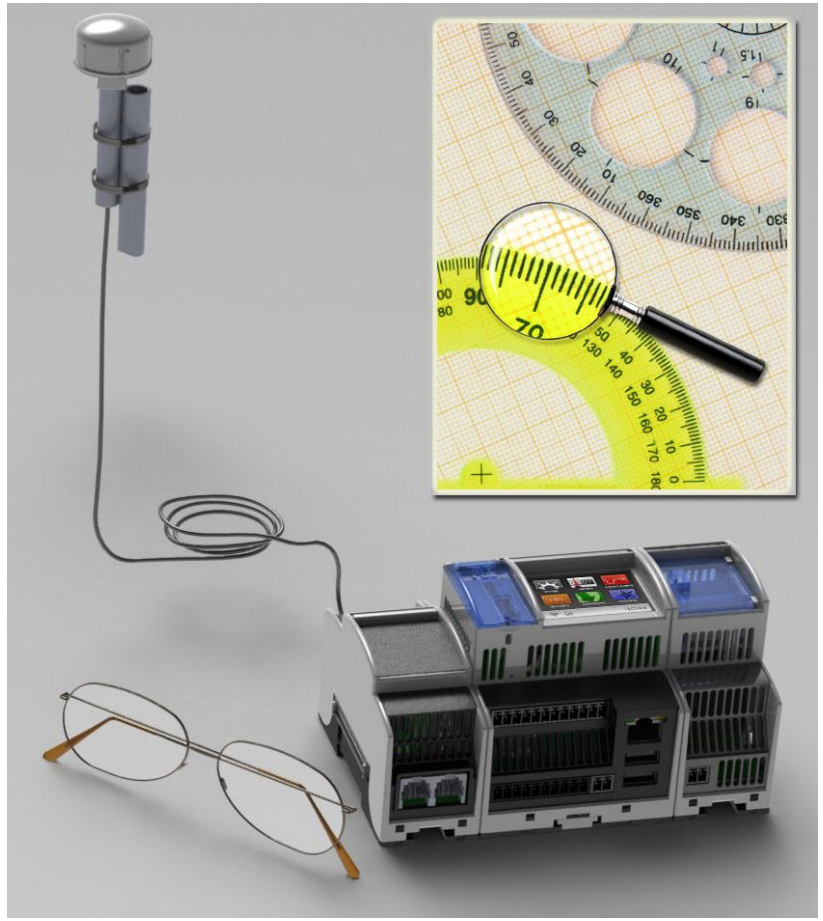


“Grid Thumper” – portable impulse response load

https://www.PowerStandards.com/product/grid-thumper/highlights/

But don’t disrupt microgrid users!

Stretching the limits of microPMU instruments



- Microgrid voltage, current, and phasor measurements
- Typical “precision AC meter” resolution ~ 0.05%

Standard microPMU

Useful magnitude resolution 0.0002%
2 PPM (parts-per-million, parts per 10^6)

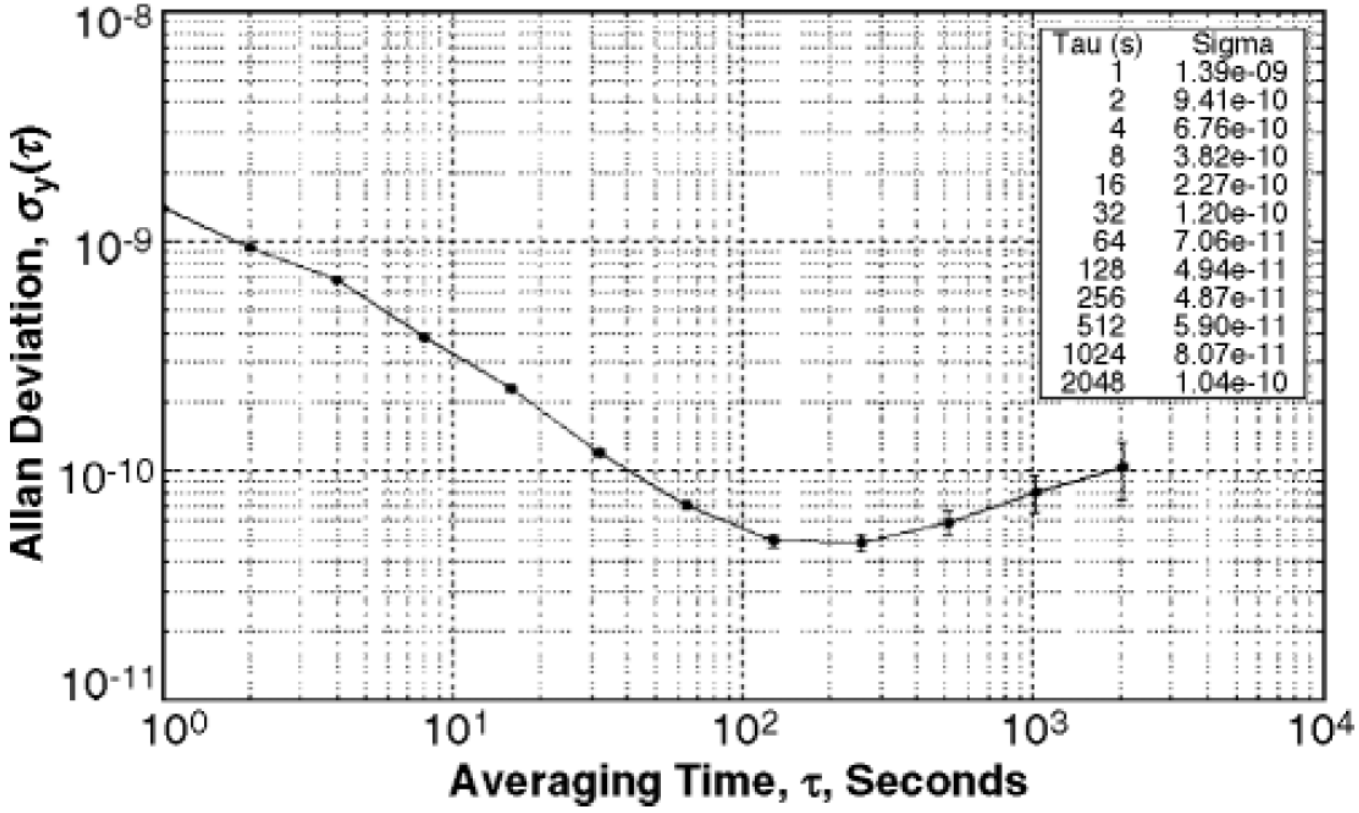
Stretched – *is it possible?*

Useful magnitude resolution 0.000001%
10 PPB (parts-per-Billion, parts per 10^9)

A useful concept: Allen variance
for thinking about the limits of noise reduction

Lombardi M.A.,
U.S. National Institute
of Standards and Technology,
Fundamentals of Time and Frequency

https://tf.nist.gov/general/pdf/1498.pdf



A useful concept: Zero-reference instrument

for increased instrument & system confidence

1% mains voltage disturbance

1000:1 AC-DC power supply rejection -> 10 ppm internal DC supply disturbance

1000:1 DC supply rejection by A-to-D reference -> 10 PPB internal reading disturbance(!)

Early experimental results using Alameda Island as the test-subject microgrid

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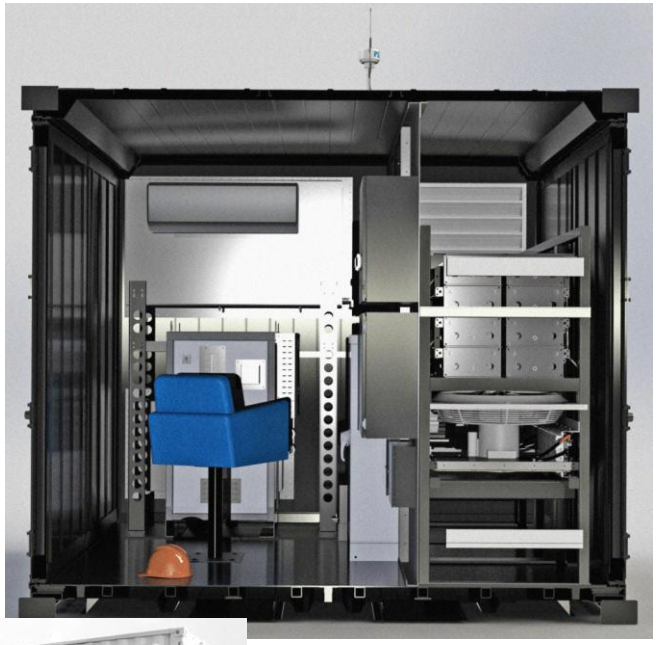
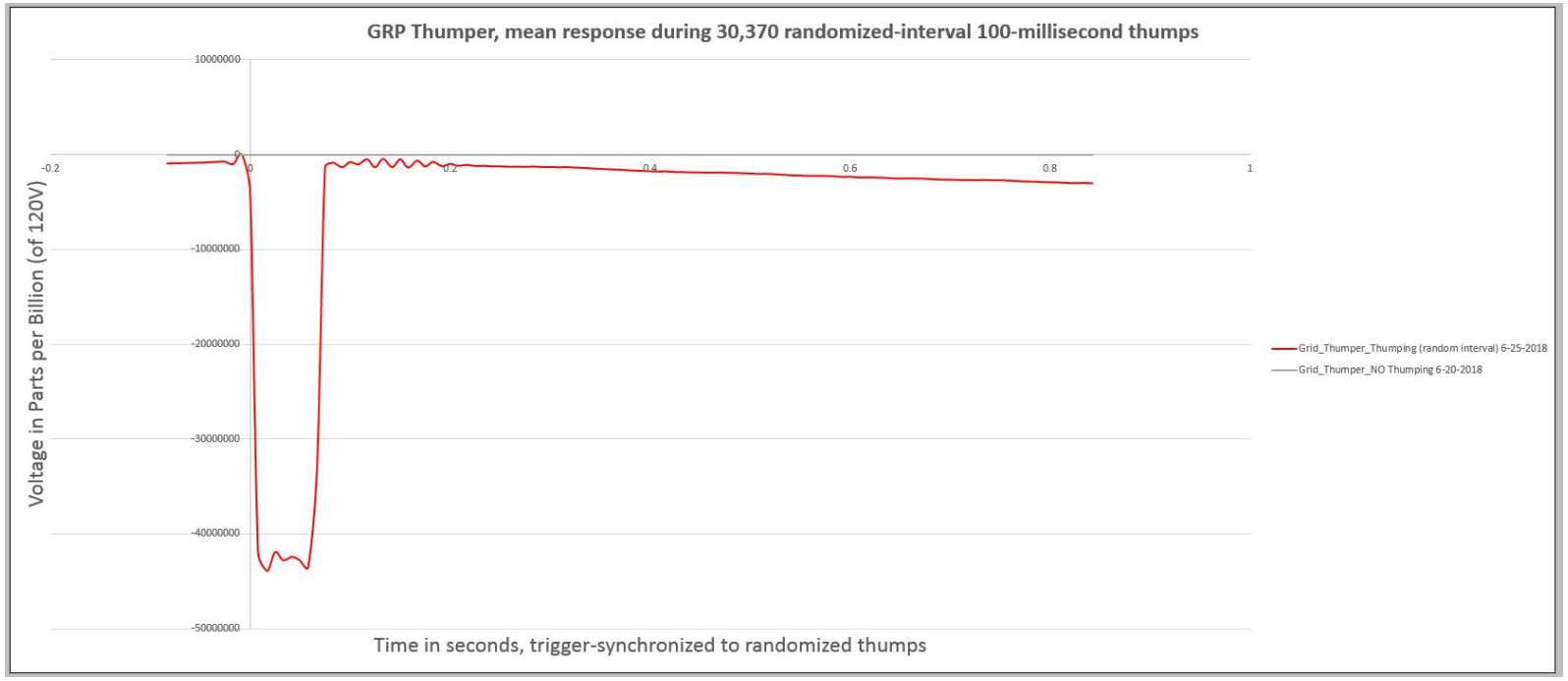
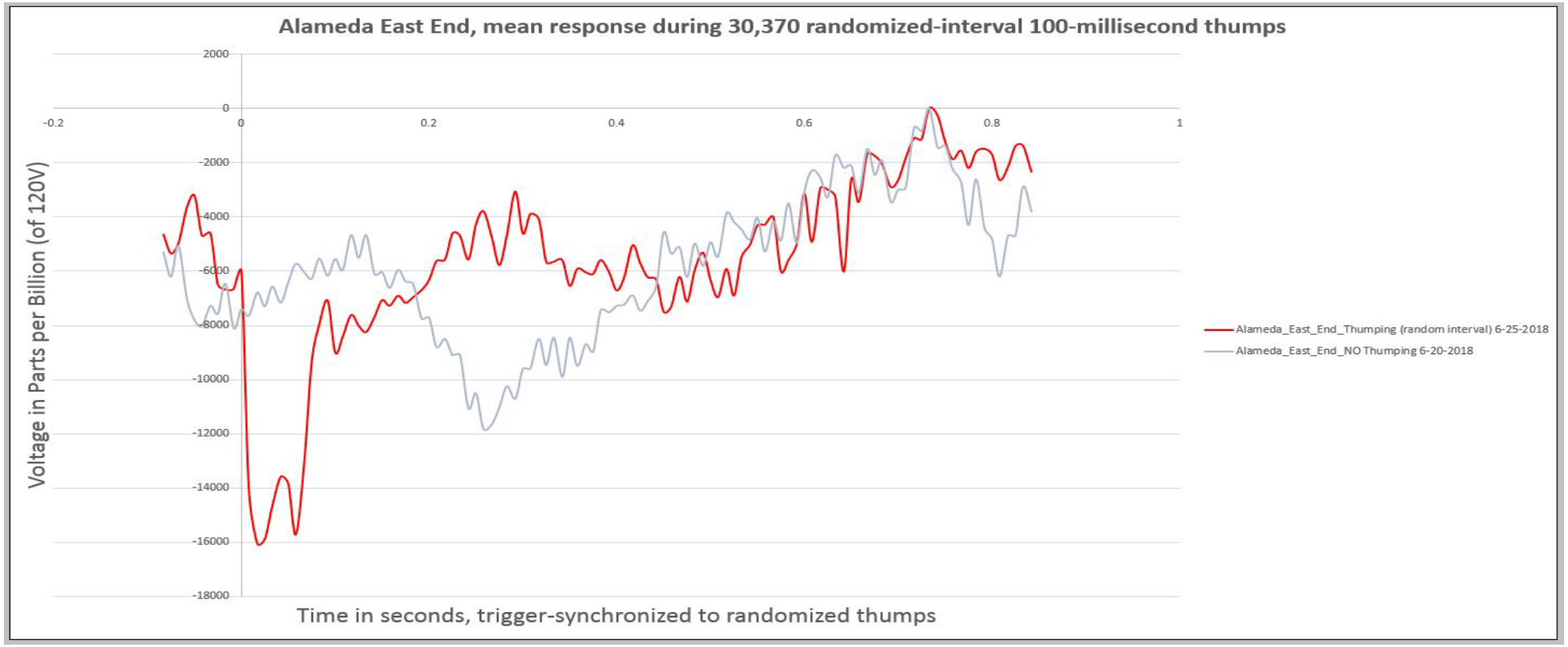


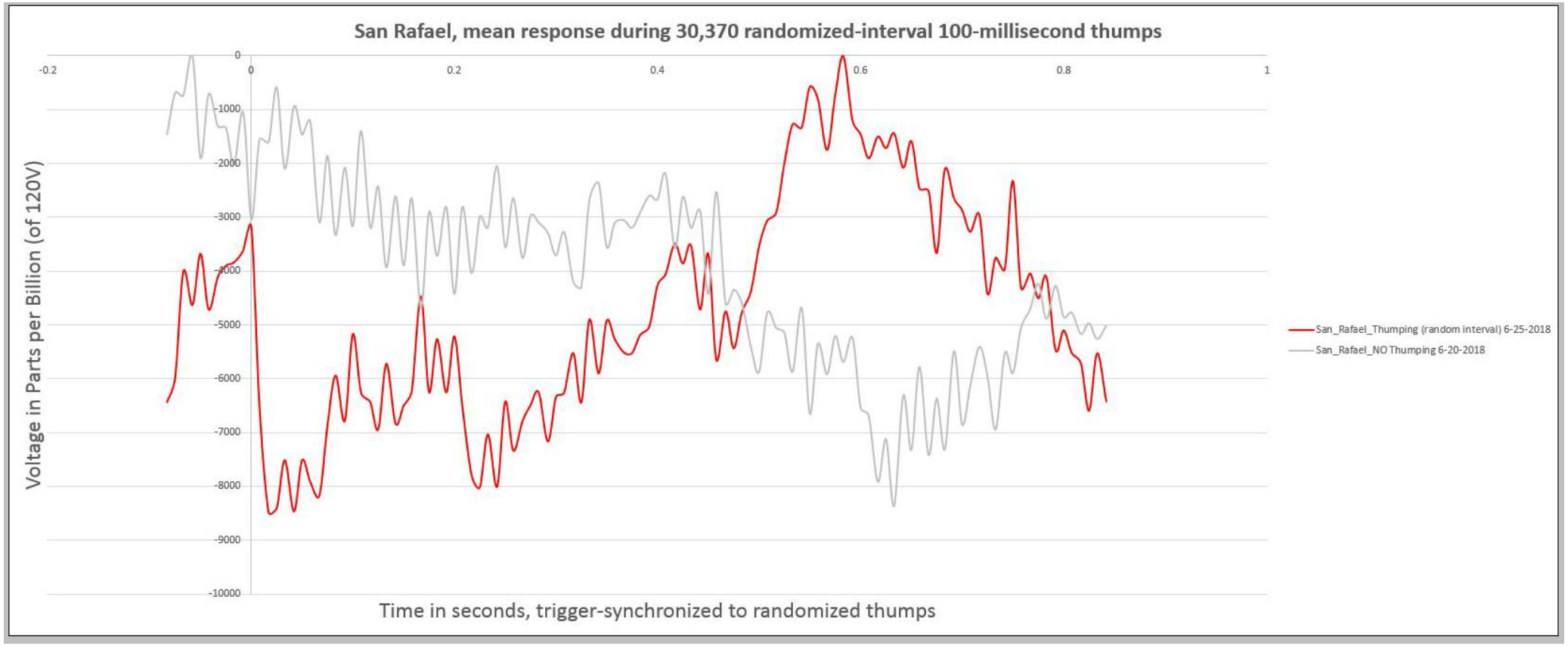


Early experimental results using Alameda Island as the test-subject microgrid *(time domain)*



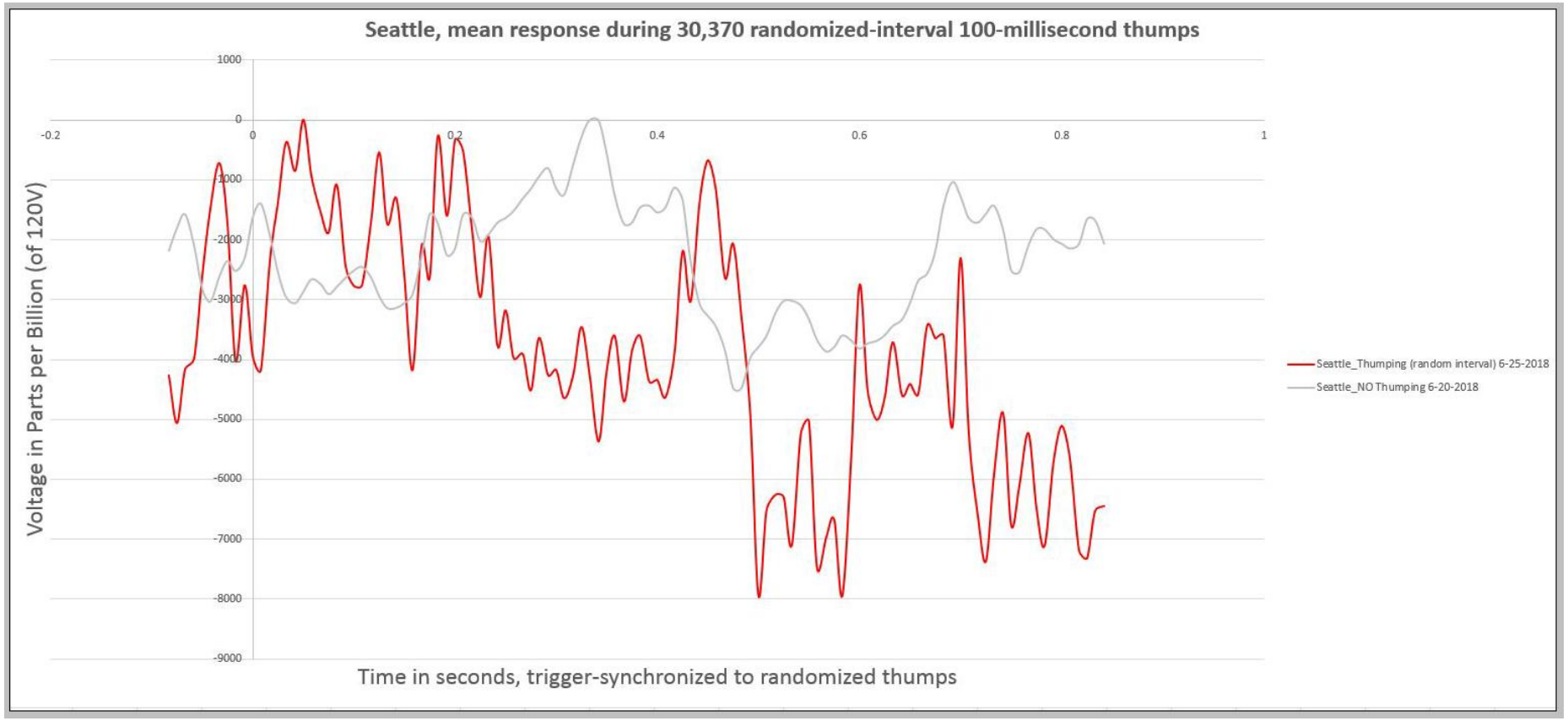
Alameda – East End (inside the "microgrid")

Early experimental results using Alameda Island as the test-subject microgrid *(time domain)*



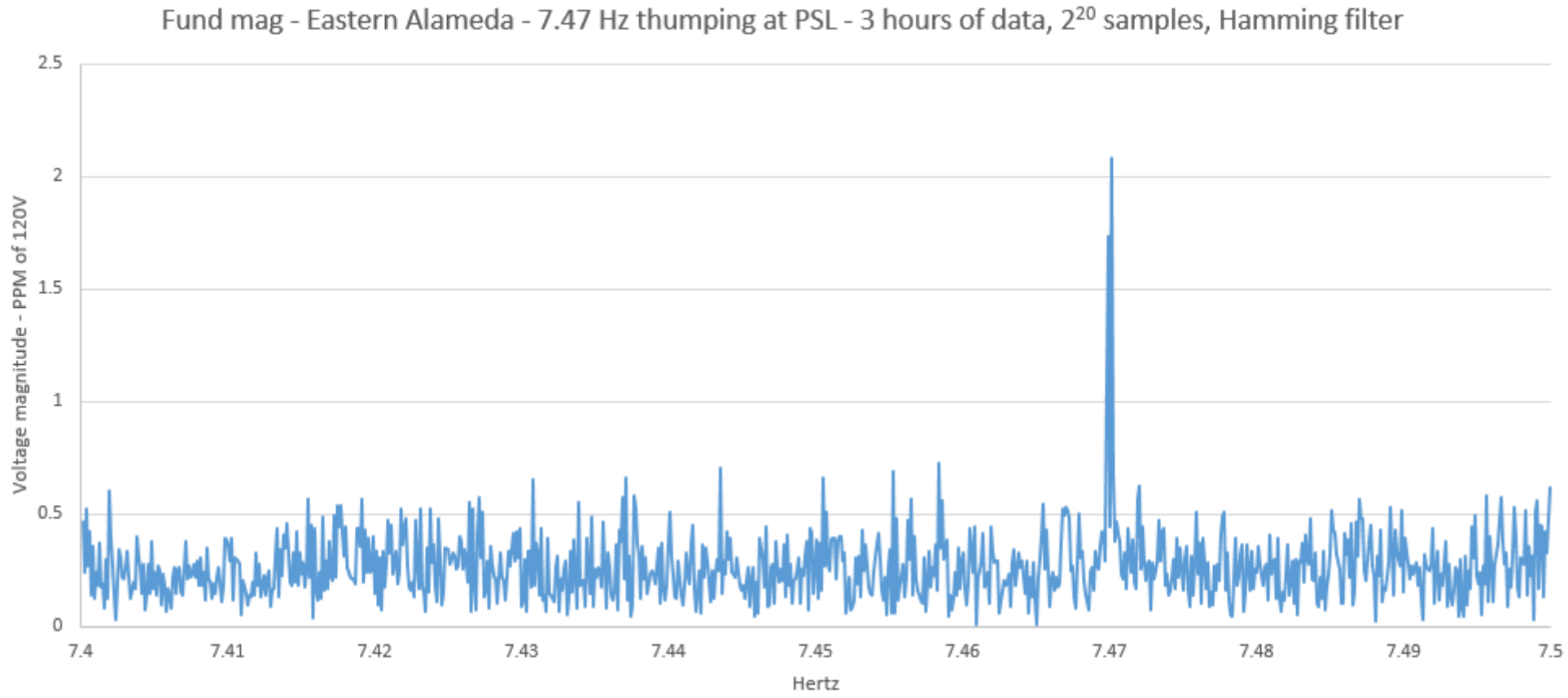
San Rafael (about 100 km)

Early experimental results using Alameda Island as the test-subject microgrid *(time domain)*



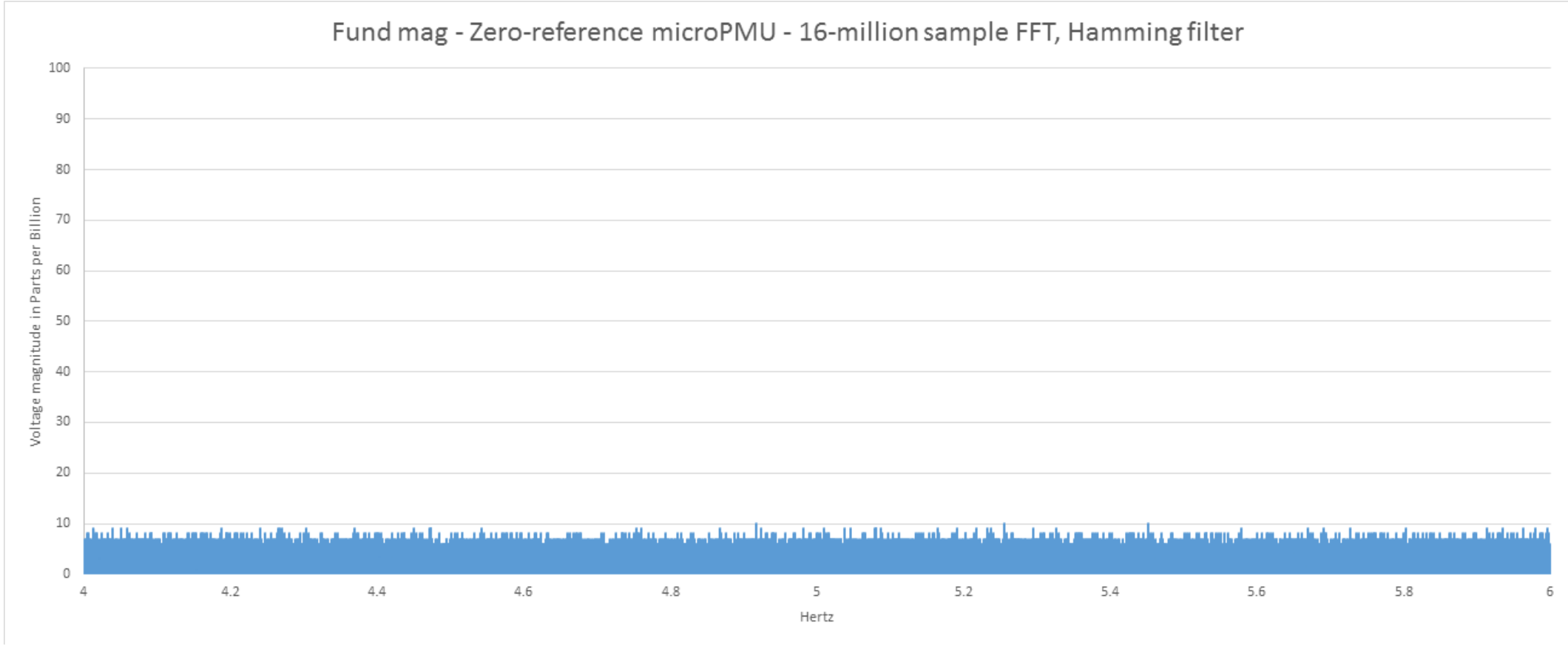
Seattle (about 1 300 km)

Early experimental results using Alameda Island as the test-subject microgrid *(frequency domain)*



East Alameda, thumping 8 km away at 7.47 Hz

Early experimental results using Alameda Island as the test-subject microgrid *(frequency domain)*



Zero-reference microPMU…

Present state of research

- Confirmed interest in microgrid and grid stability
- Grid Thumper designed, constructed, tested, commissioned
  - Transportable (half-size standard shipping container)
  - 50/60 Hz, 100V~600V, 1-phase or 3-phase. Programmable up to 1 MW pulses.
  - Satellite synchronization, remote operation from PSL Global
- Stage of project today: experiment – analyze - re-experiment
- Very encouraging results so far
  - Grid instability observed
  - Parts-per-billion resolution confirmed (3 orders of magnitude better)
- Very likely to be useful – worth pursuing further research. **Project ideas?**
- *Nothing published yet… this is our first "quiet" public discussion.*

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