Photovoltaic DC Arc Fault Detector Testing at Sandia National Laboratories

Jay Johnson[1], Birger Pahl[2], Charles Luebke[2], Tom Pier[2], Theodore Miller[3], Jason Strauch[1], Scott Kuszmaul[1], and Ward Bower[1]

[1] Sandia National Laboratories, Albuquerque, NM

[2] Eaton Corporation, Milwaukee, WI

[3] Eaton Corporation, Pittsburgh, PA

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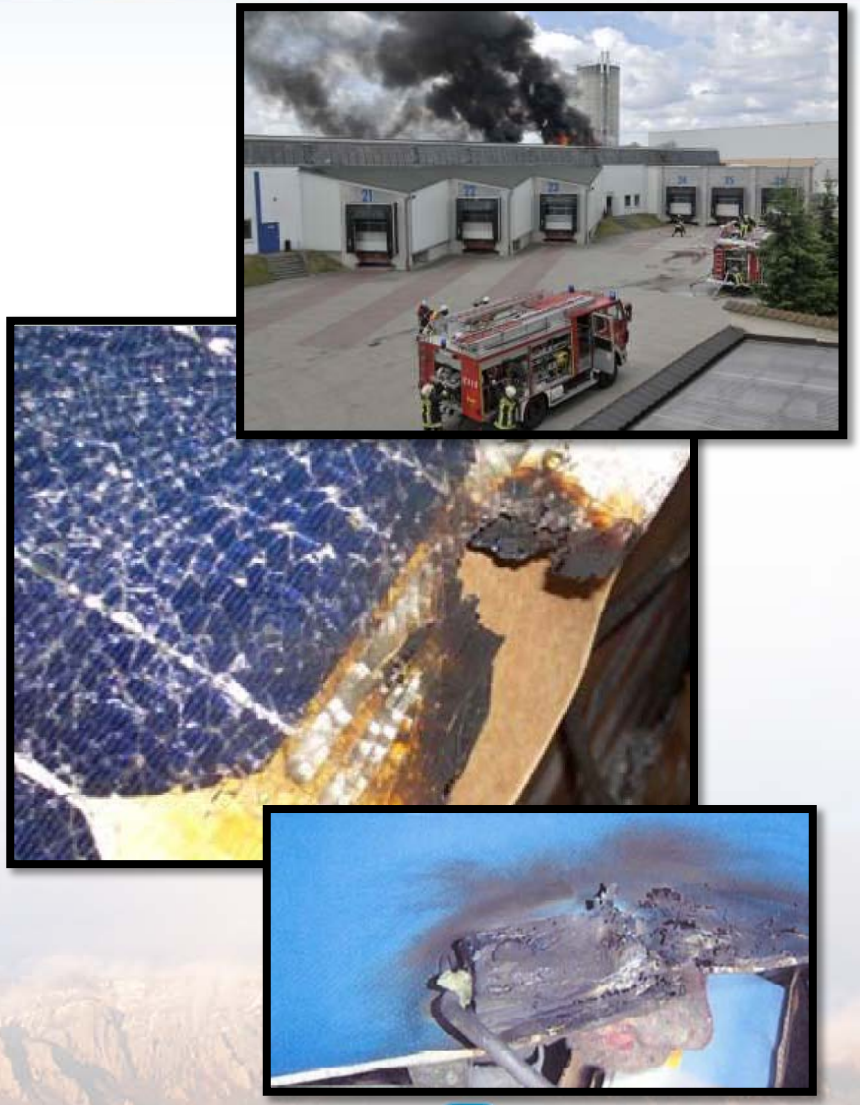
Presentation Outline

- **PV Arc Fault Background**
- **Sandia National Labs Overview**
- **Arc Fault Detection Challenges**
- **Arc Fault Experiments**
  - Inverter noise
  - Arcing noise
  - Arc vs baseline comparison on multiple PV strings
- **Conclusions**



Sandia Contribution to PV Arc Fault Detection and Mitigation Requirements

Arc faults in PV systems cause fires.

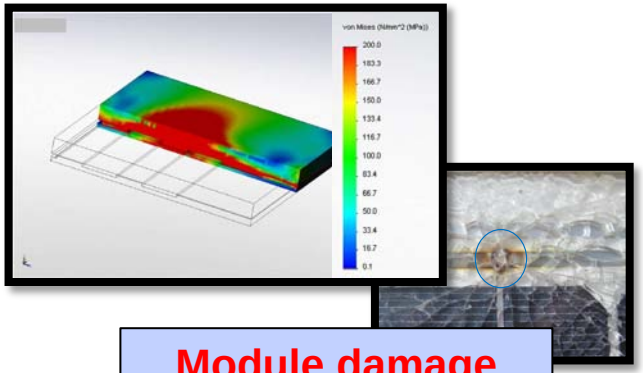
2011 *National Electrical Code*® requires detection and interrupt of arc faults in PV systems.

Industry responds by creating PV AFCI devices.

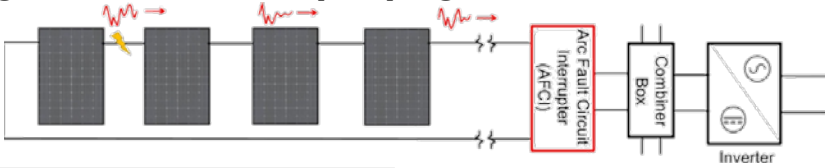
Sandia research helps industry make better products.

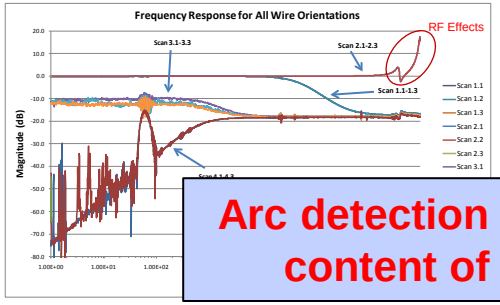
Industry works with Sandia to test AFCIs.

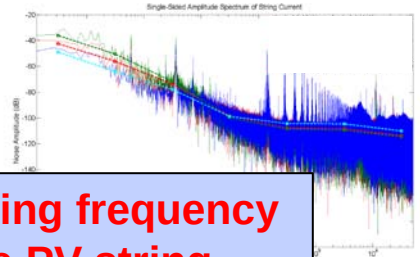
Sandia Research: Arc modeling and electrical propagation studies.



Module damage modeling







Arc detection using frequency content of the PV string

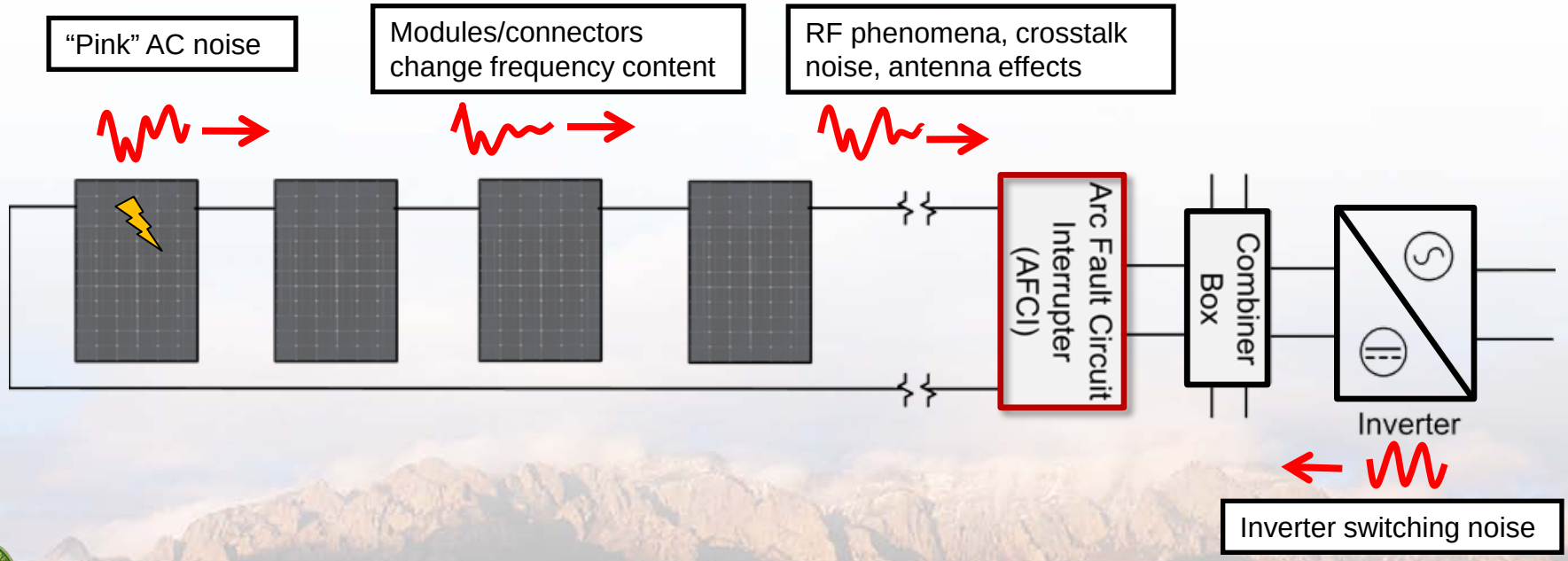
Why Test Arc Detection at Sandia National Laboratories?

- **Sandia National Labs is a resource for PV companies, technologies, and components.**
  - SNL has partnerships with inverter, module, BOS components, AFD, and AFCI manufacturers.
- **Distributed Energy Technologies Laboratory (DETL)**
  - Test bed for novel renewable energy technologies.
  - Reconfigurable PV arrays with diverse portfolio of PV technologies:
    - Different manufacturers, ages, and I-V characteristics
    - Range of connectors, DC disconnects, combiner boxes, line lengths, and inverters.
- **UL Subject 1699B does not cover all testing cases or scenarios.**
  - DETL can demonstrate AFCI robustness.

Distributed Energy Technologies Laboratory

Arc Fault Detection Challenges

- **Some AFCIs use the AC frequency content of the string for detection**
- **Two challenges involved with arc detection using a remote arc fault detector:**
  1. Missed or delayed detection due to arc frequency attenuation in PV components (e.g., modules, connectors, bypass diodes)
  2. Nuisance tripping due to noise from electromagnetic coupling (crosstalk), inverter switching, and radio frequency (RF) effects



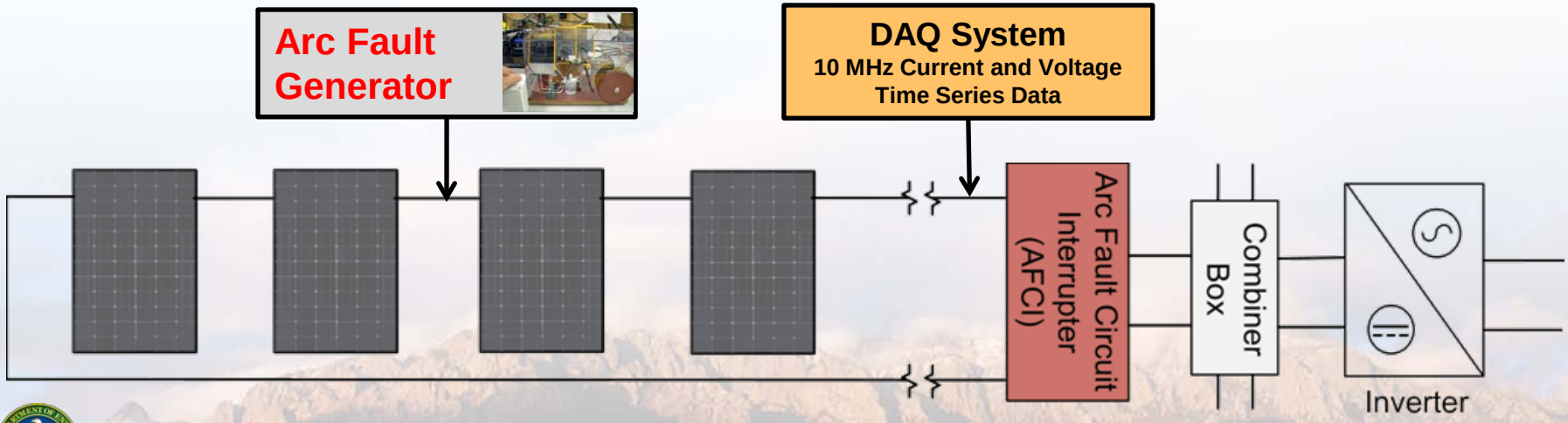
Arc Fault Experiments

Questions

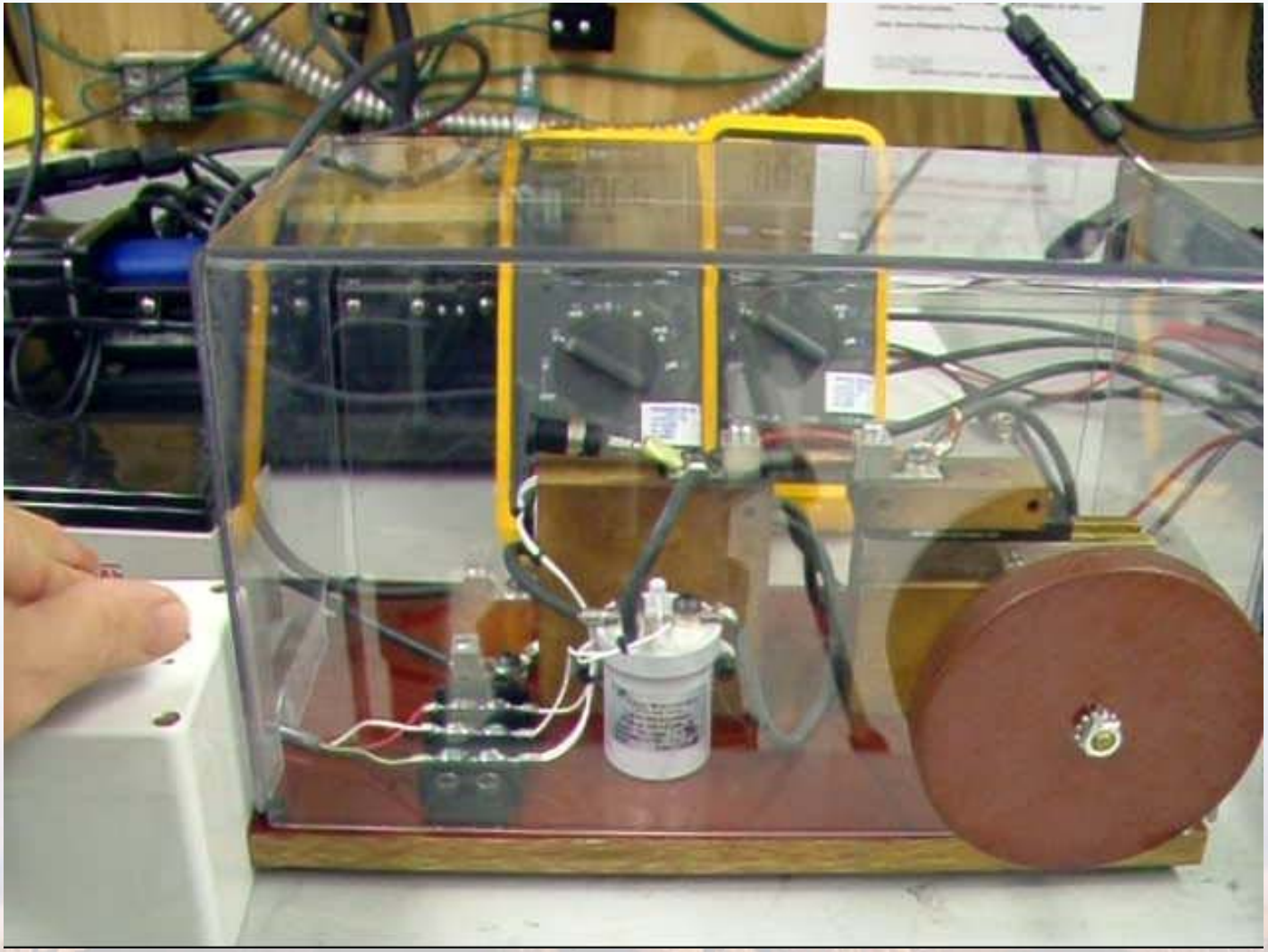
- **What is the influence of inverters on string noise?**
- **Are there frequency bands which are excited with an arc?**
- Does crosstalk trip the AFCI?
- Do antenna effects and RF phenomenon influence detection?
- Does arc fault location change the arcing frequency content?
- Do DC/DC converters change the PV string AC spectrum?

PV String Testing Options at DETL

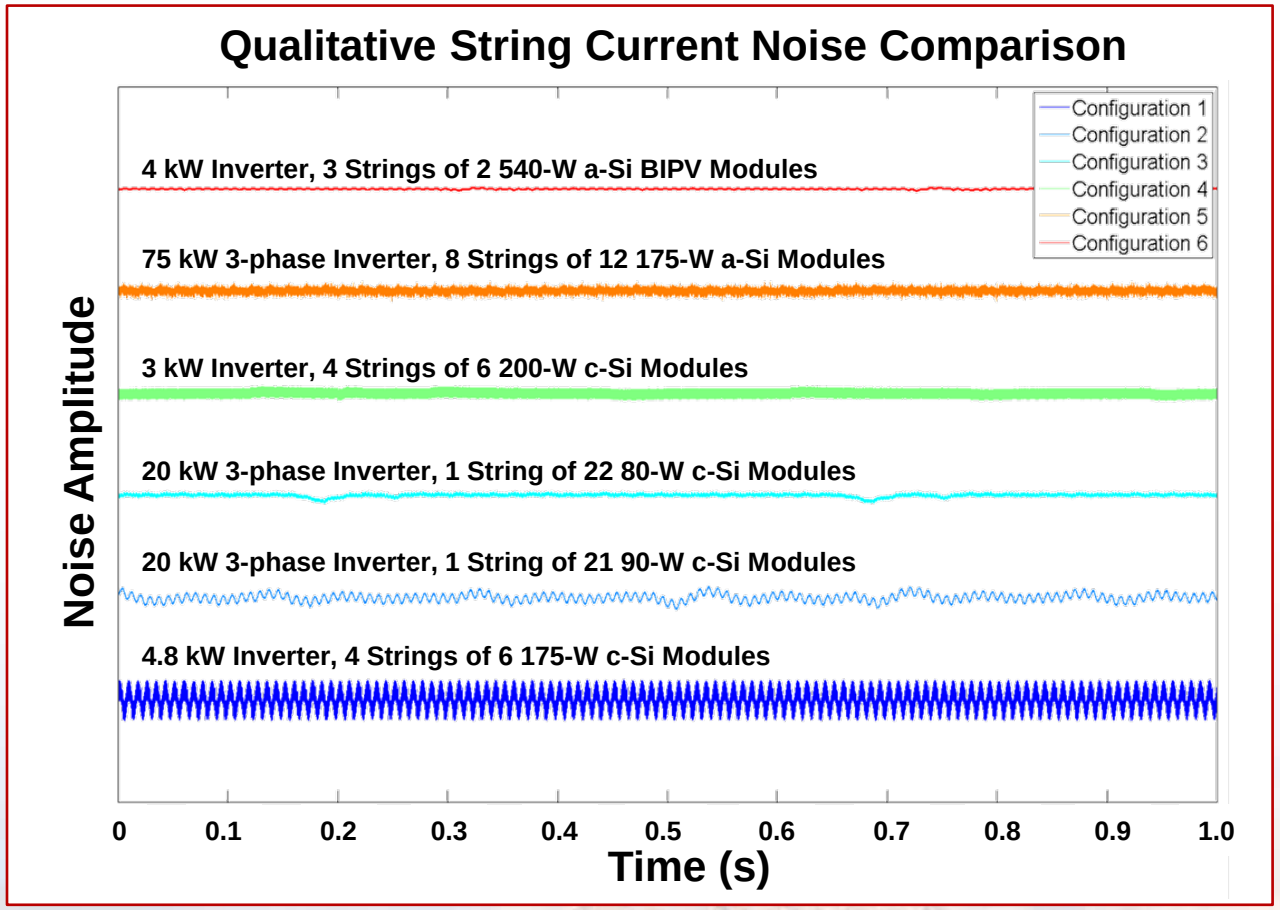
Basic Testing Setup

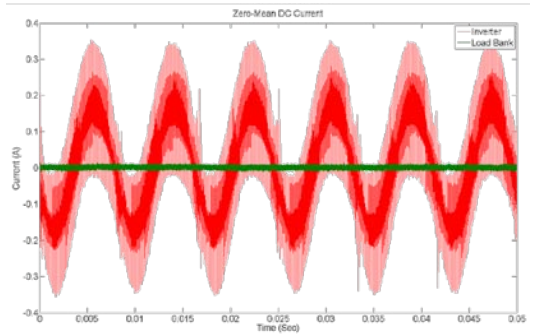


Simulated Arc Fault

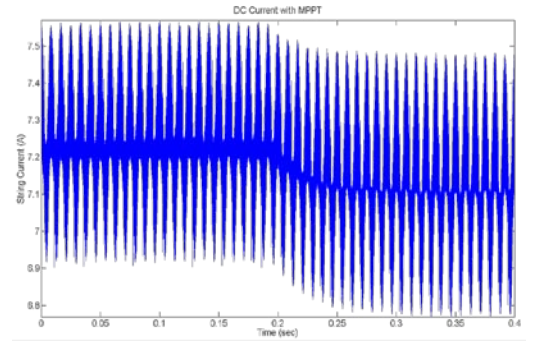


String Noise Varies with Inverter Type, PV Module Technology, and Array Topology



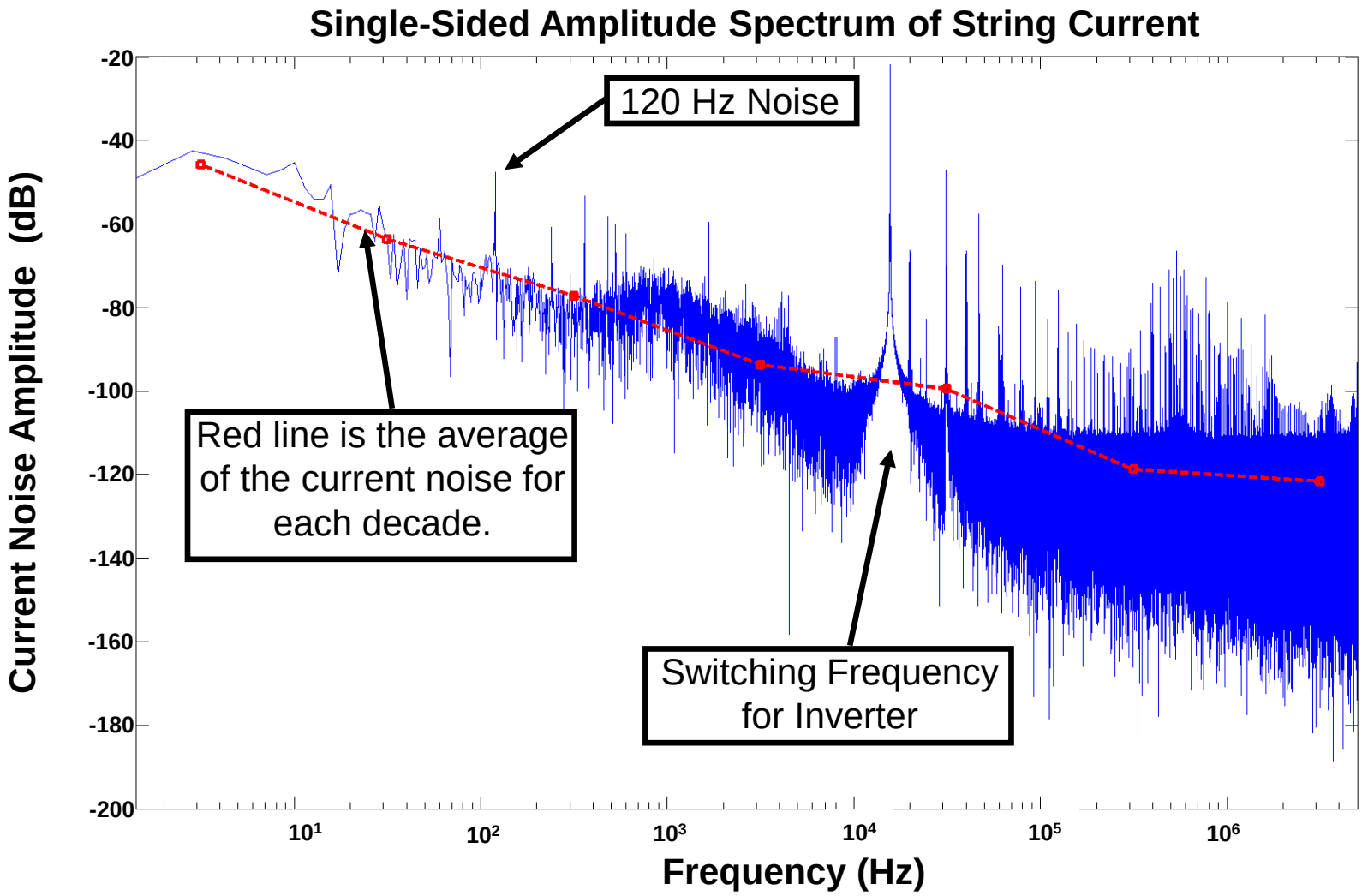


120 Hz noise from the inverter compared to a resistive load bank noise.



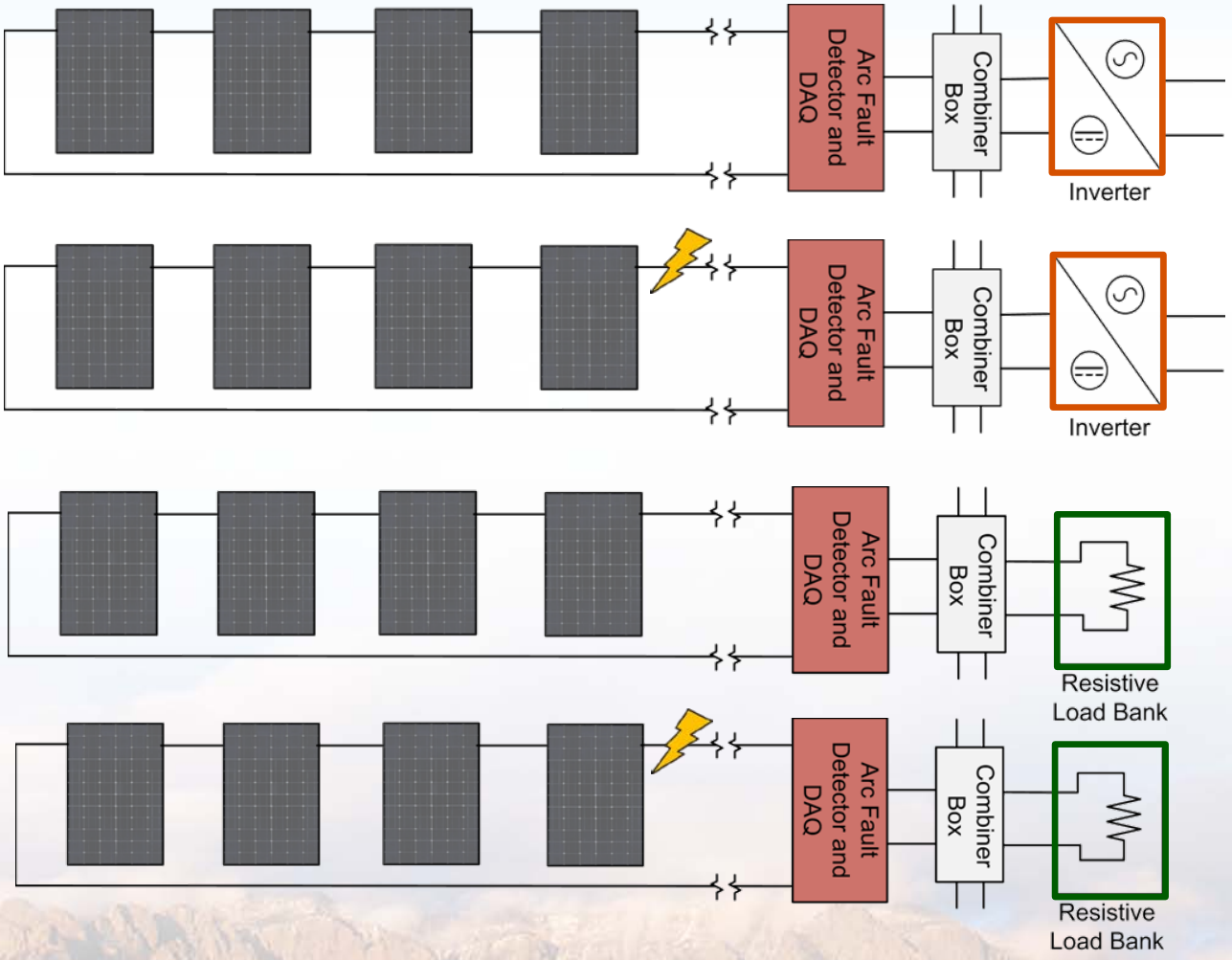
MPPT effect on current.

String Noise in Frequency Domain

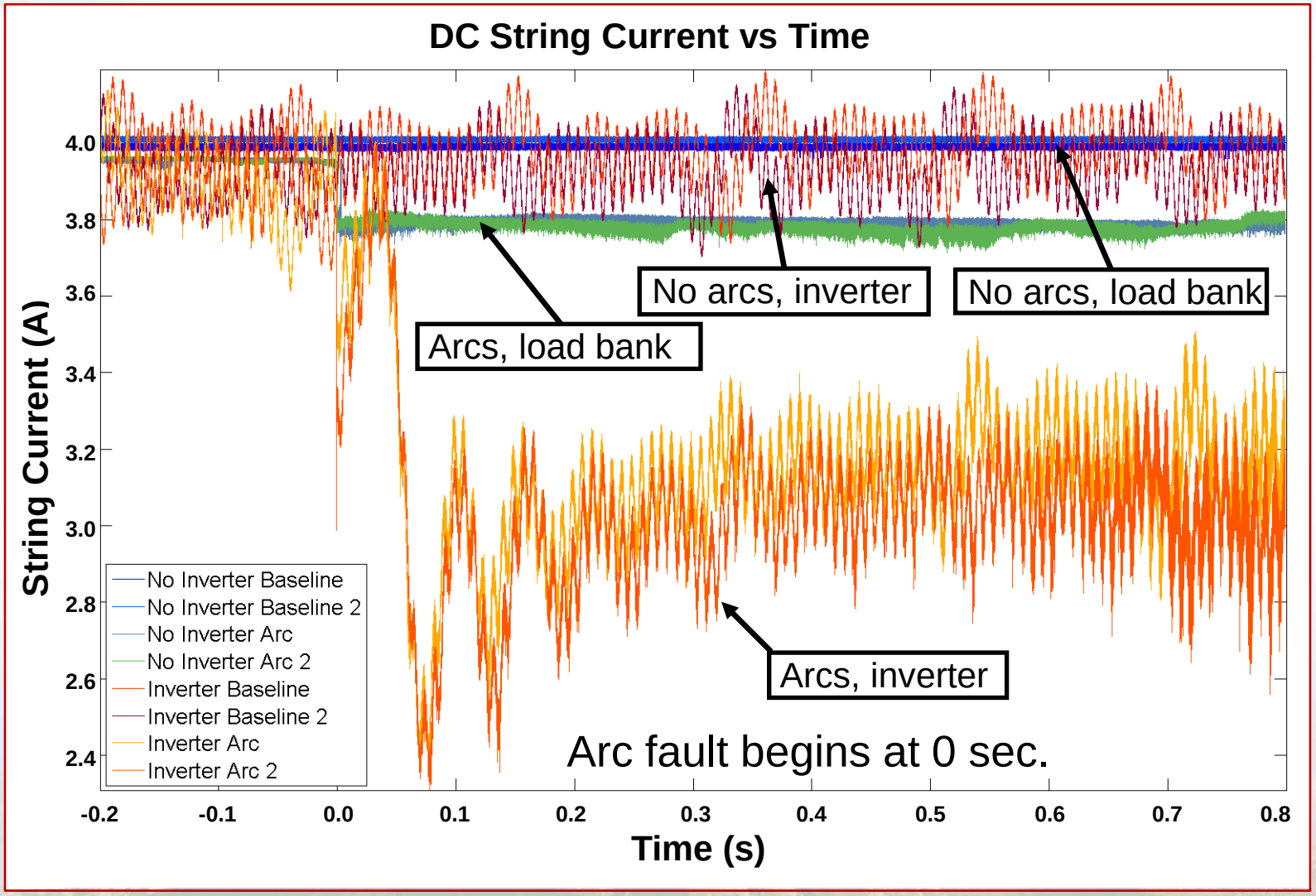


Testing Configurations

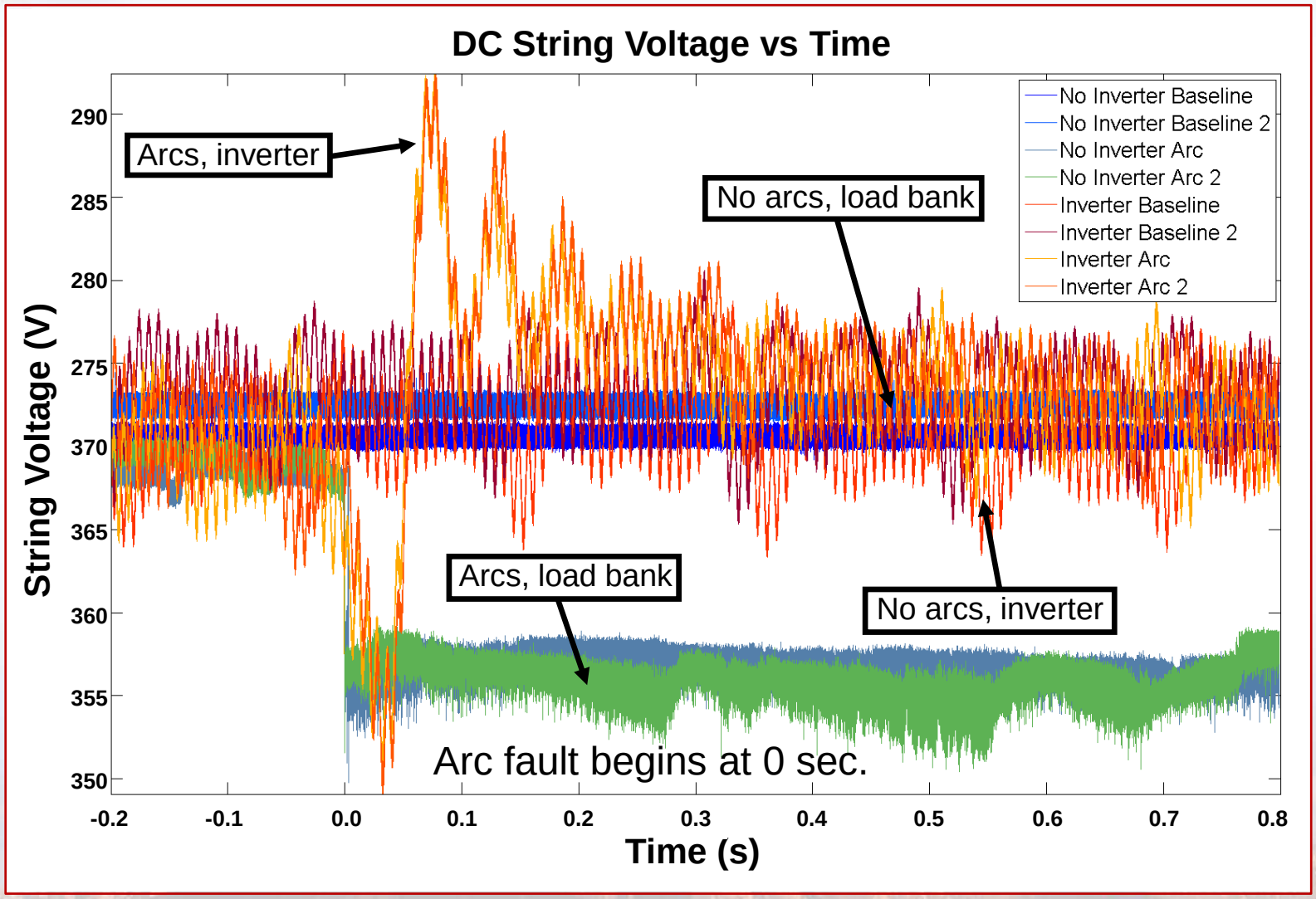
- **Baseline** with an inverter.
- **Arc** with an inverter.
- **Baseline** without an inverter
- **Arc** without an inverter



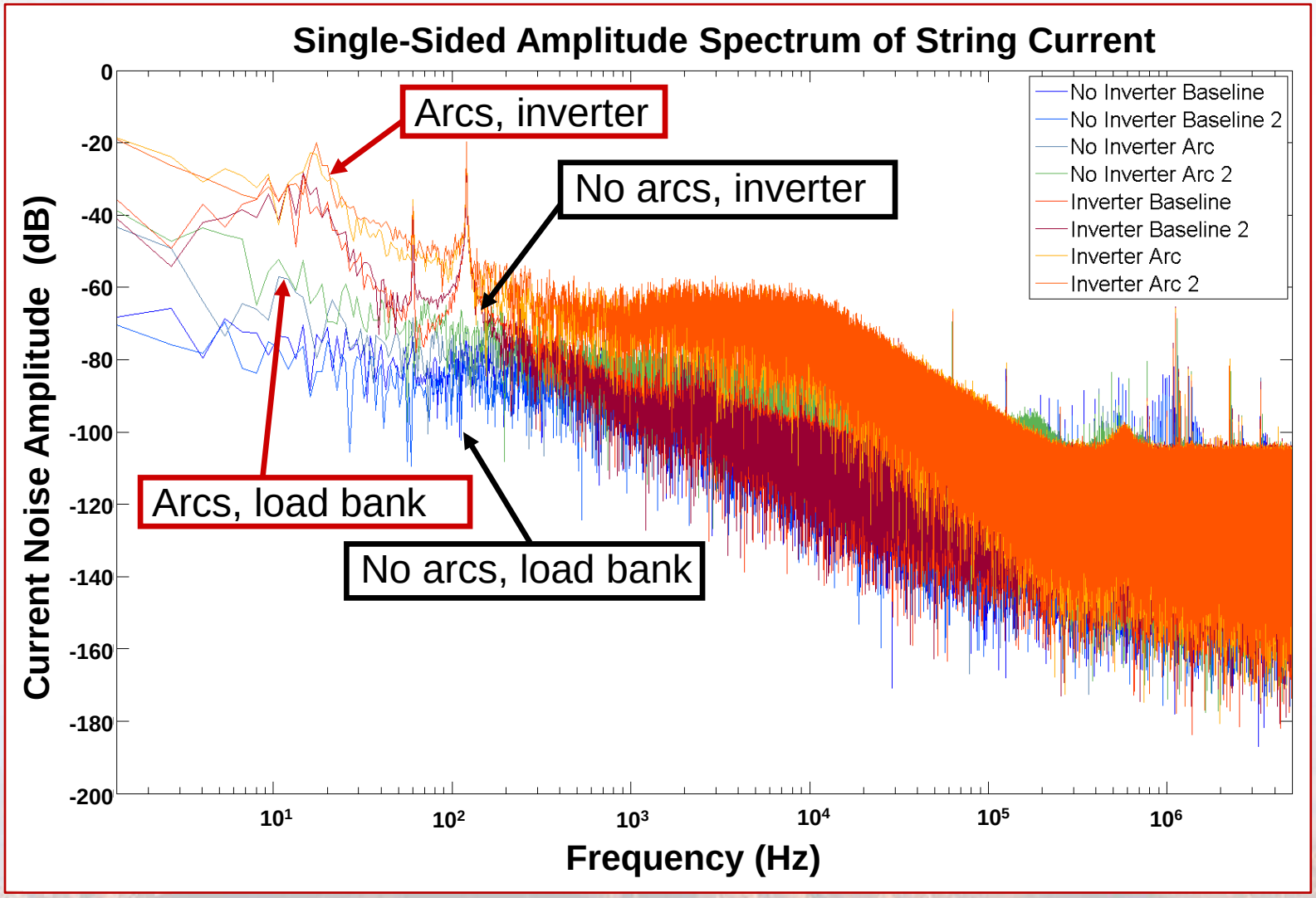
DC String Current during an Arc Fault



DC String Voltage during an Arc Fault

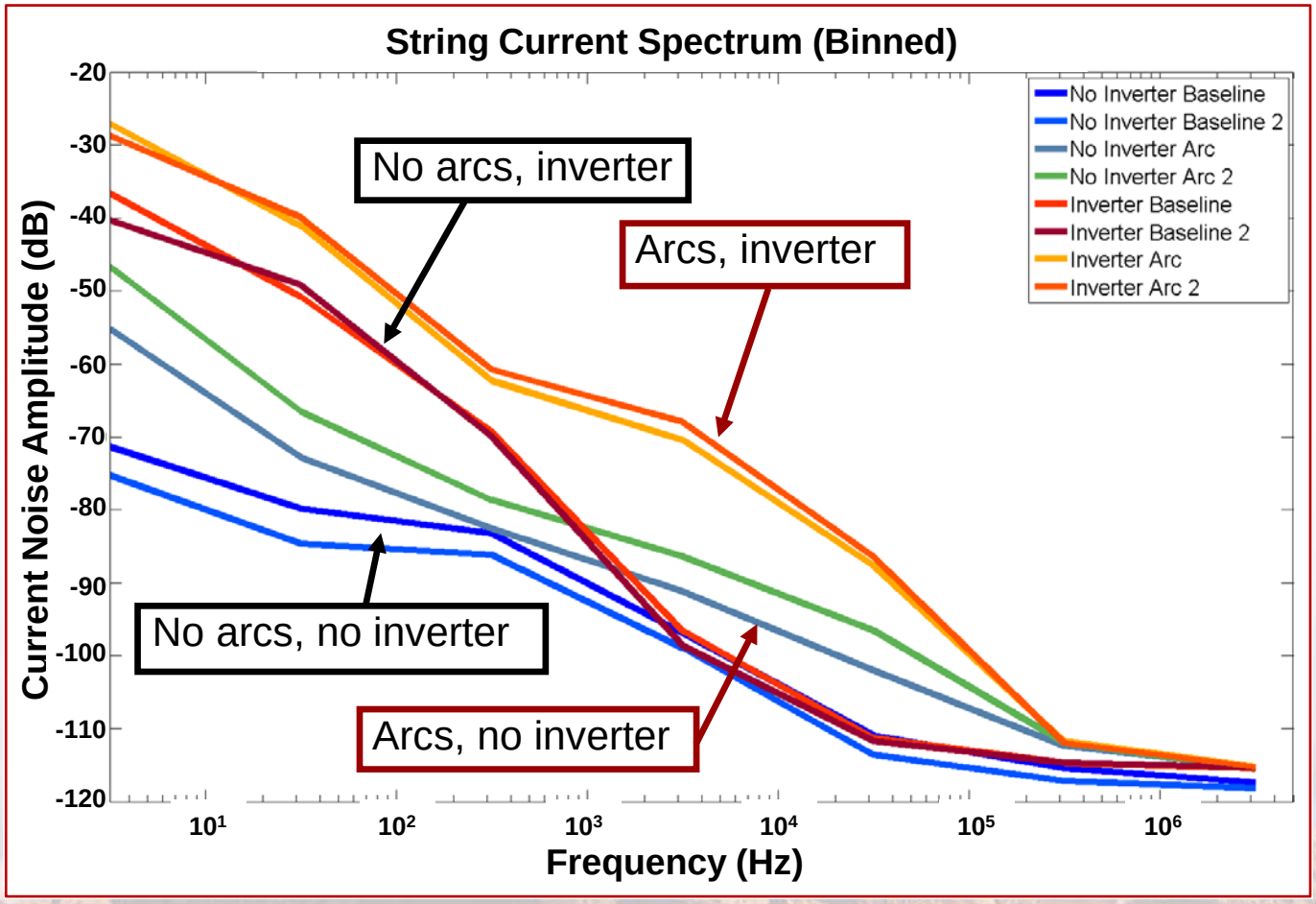


AC Arc Fault Frequencies on PV Strings



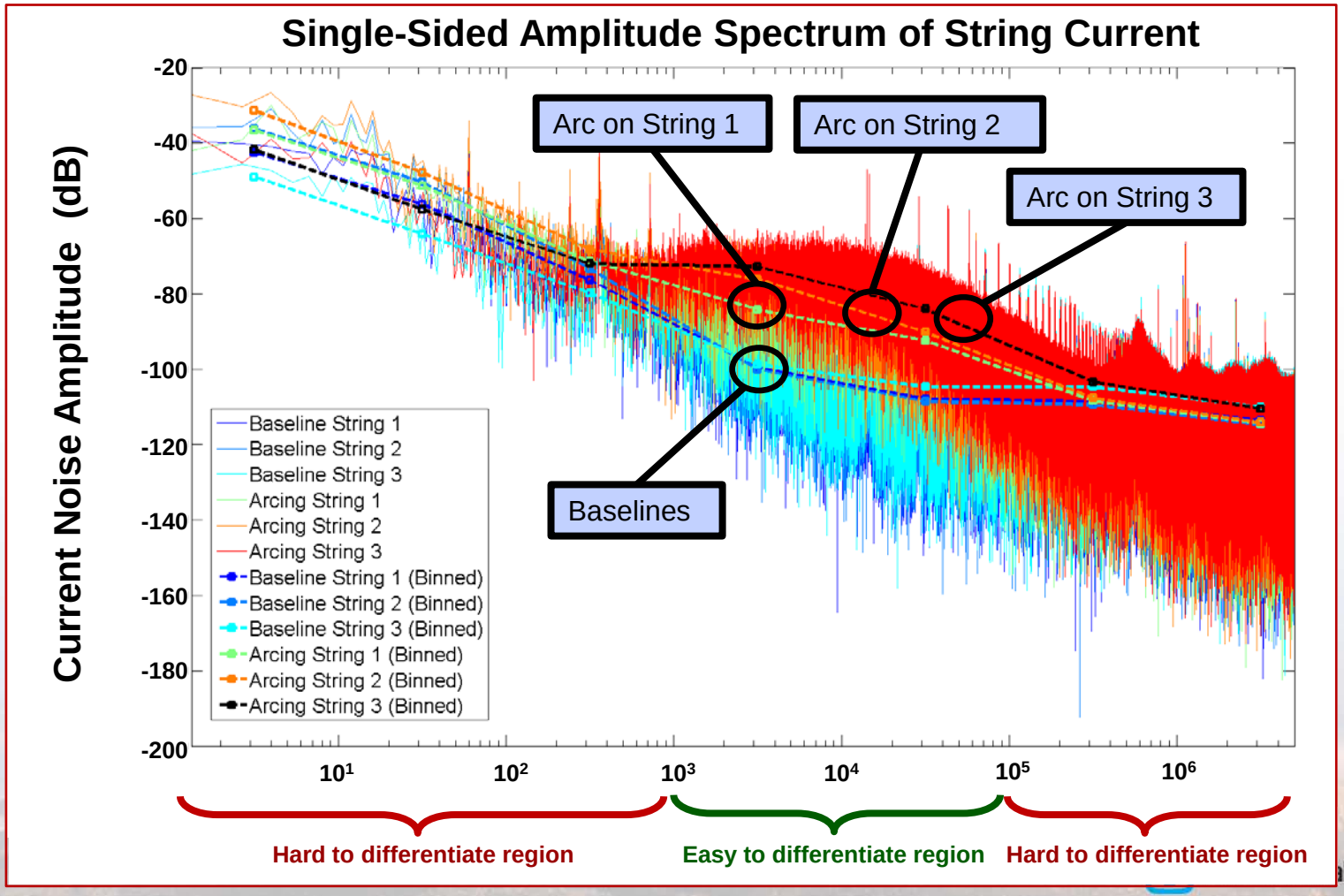
Binned Arc Current and Voltage Frequencies

- What's the best way to differentiate arcing and non-arcing strings?



Arc Fault Generation on Arrays

- **Same 3-phase inverter with 3 different strings:**
  - 21 90-W c-Si modules, 22 80-W p-Si modules, 22 80-W c-Si modules



Conclusions

- **2011 *NEC* requires DC arc fault circuit protection on photovoltaic systems with dc source circuits, dc output circuits, or both, on or penetrating a building operating at a PV system maximum system voltage of 80 volts or greater.**
- **Sandia National Laboratories provides an excellent testing facility for arc fault detectors and arc fault circuit interrupters because of the diversity of PV technologies.**
- **Experimental work with Eaton has revealed some avenues for robust detection as well as some arc fault detection challenges.**
  - Arcing can excite certain frequency bands above the baseline (non-arcing) levels.
  - Inverters generate a lot of baseline noise across the spectrum, but especially at 120 Hz, switching frequencies and harmonics.
- **Additional experimentation is recommended to further understand arcing phenomenon and signal propagation in a broad range of PV systems.**

Acknowledgements

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Questions?

Contact Information

Jay Johnson
Sandia National Labs
Phone: 505-284-9586
jjohns2@sandia.gov

Charles Luebke
Eaton Corporation
Phone: 414-449-7264
CharlesJLuebke@eaton.com