Orchestrating a brighter world NEC

NREL

ECOC 2024 Th1F.2

Remote Sensing for Power Grid Fuse Tripping Using AI-Based Fiber Sensing with Aerial Telecom Cables

Zhuocheng Jiang[(1)], Yue Tian[(1)], Wataru Kohno[(1)], Sarper Ozharar[(1)], Yangmin Ding[(1)], Ting Wang[(1)], Yiyun Yao[(2)], Fei Ding[(2)]

Presenter: Ming-Fang Huang[(1)]

[(1)] NEC Laboratories America Inc., Princeton, NJ, USA,

[(2)] National Renewable Energy Laboratory, Golden, Colorado, USA

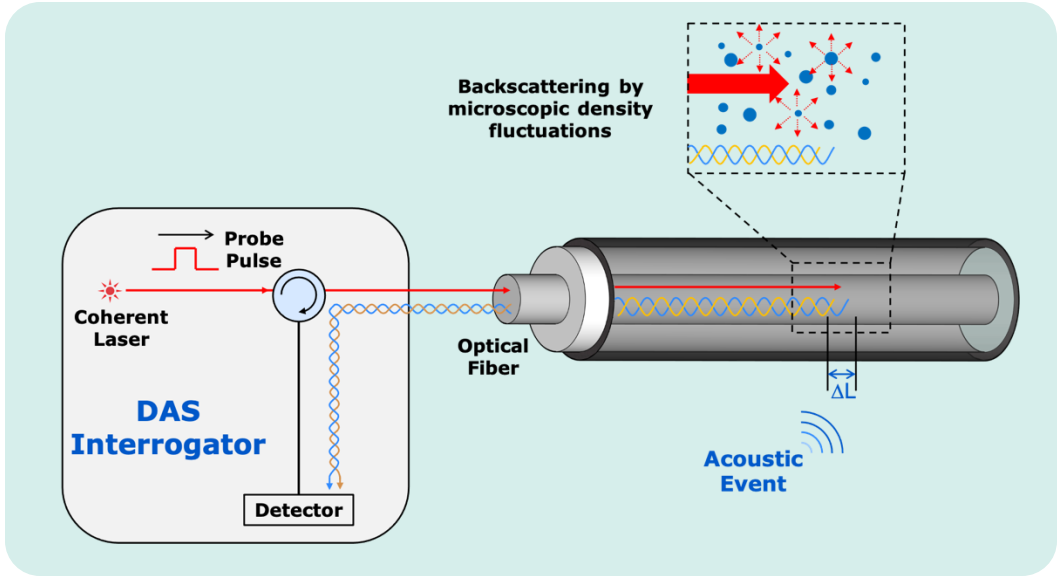
Outline

1. Motivation
2. Testbed and experimental setup
3. Experimental results
4. Summary

Can Field Fibers Generate Additional Values Beyond Data Transmission?

- Distributed Acoustic Sensing has enabled many applications

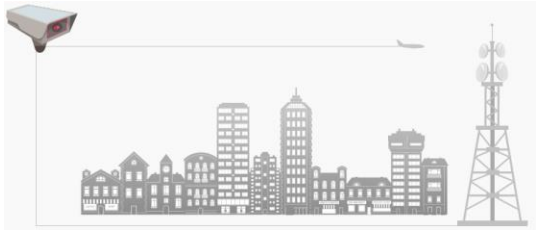
Cable cut prevention



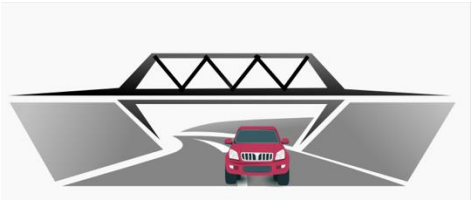
Weather event monitoring

Geographic hazards monitoring

Biological activity monitoring



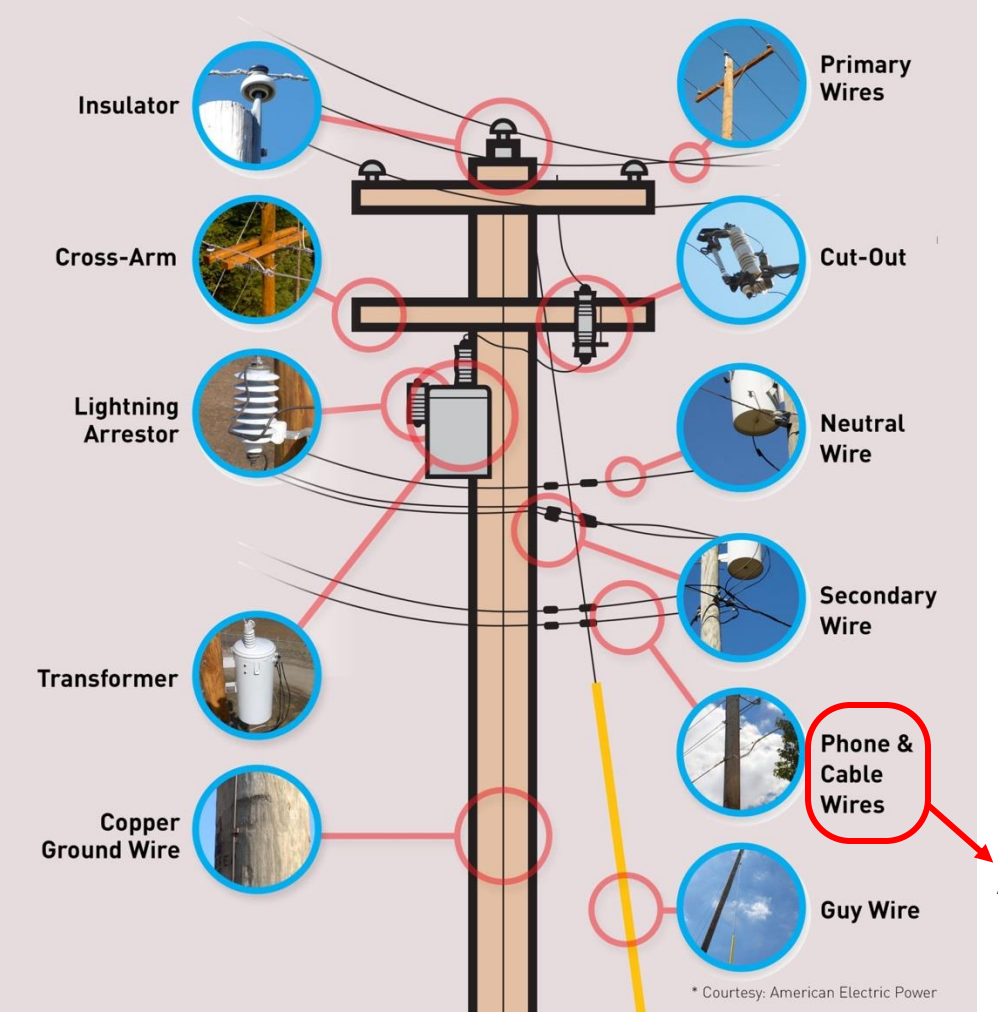
Facility security monitoring



Road and traffic monitoring

Utility Poles Connecting Telecom Fibers and Power Utility Equipment

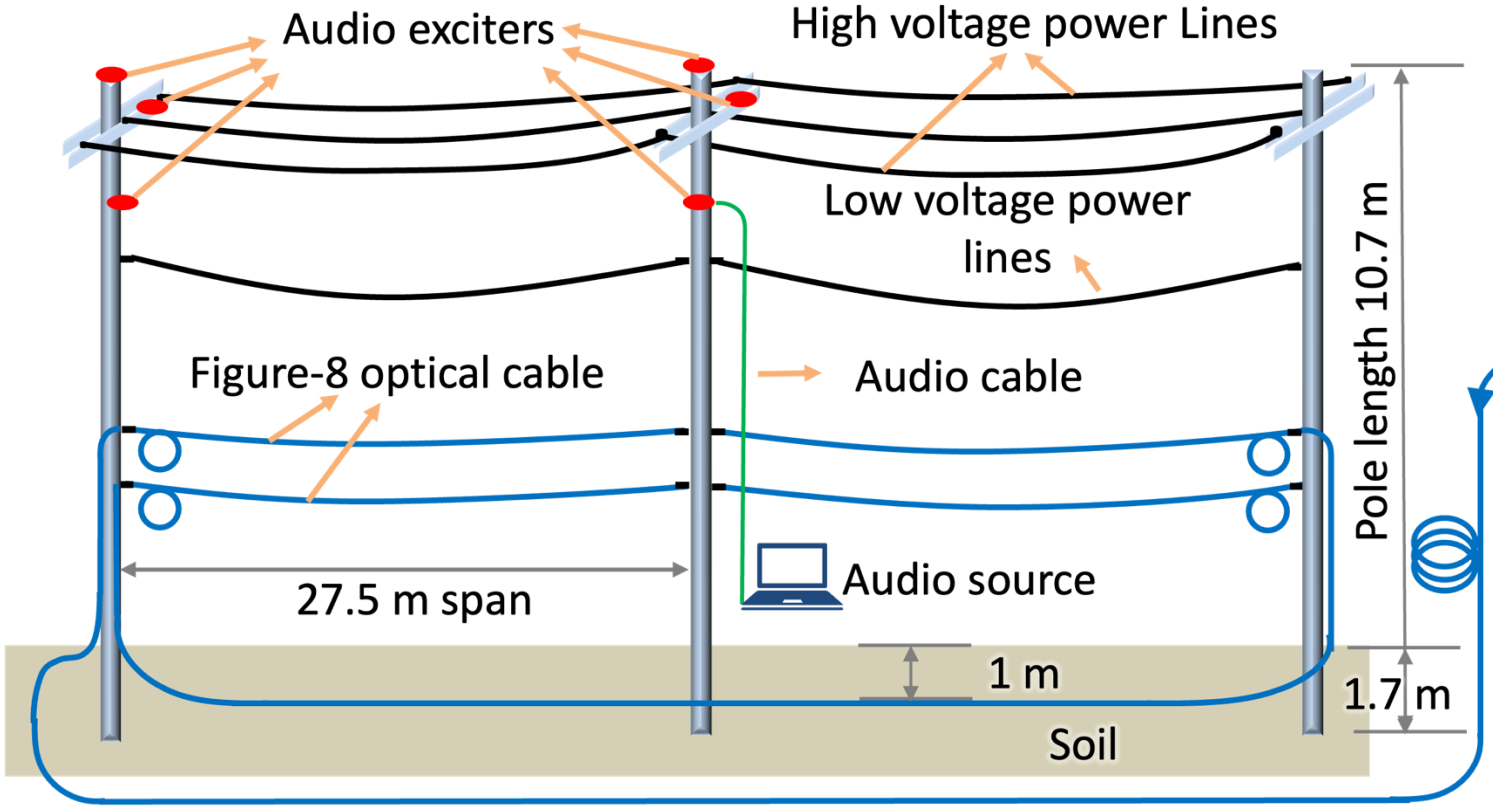
Basic equipment on a typical utility pole



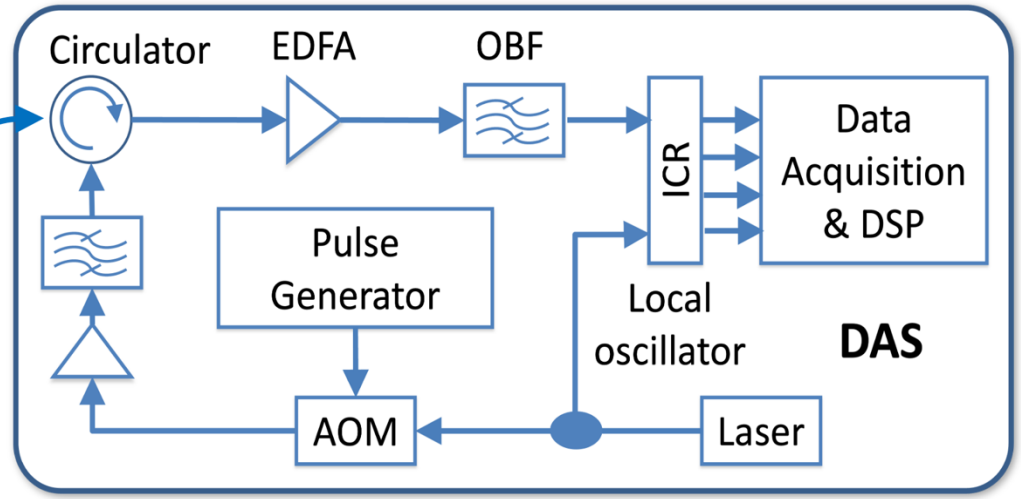
Aerial fiber cables owned by telecom carriers

- Sense power equipment anomaly by aerial fiber cables on the same poles.
- Remote, real-time sensing pinpoints malfunction equipment without a truck roll.
- Keep sensing during a power outage with no requirement for local power supply.
- This work focuses on fuss cut-out tripping detection, which may enable faster power outage sensing and restoration.

Experimental Setup on a Real-Scale Pole Testbed



AOM: Acousto-optic modulator
EDFA: Er-doped fiber amplifier
OBF: Optical bandpass filter
ICR: Integrated coherent receiver



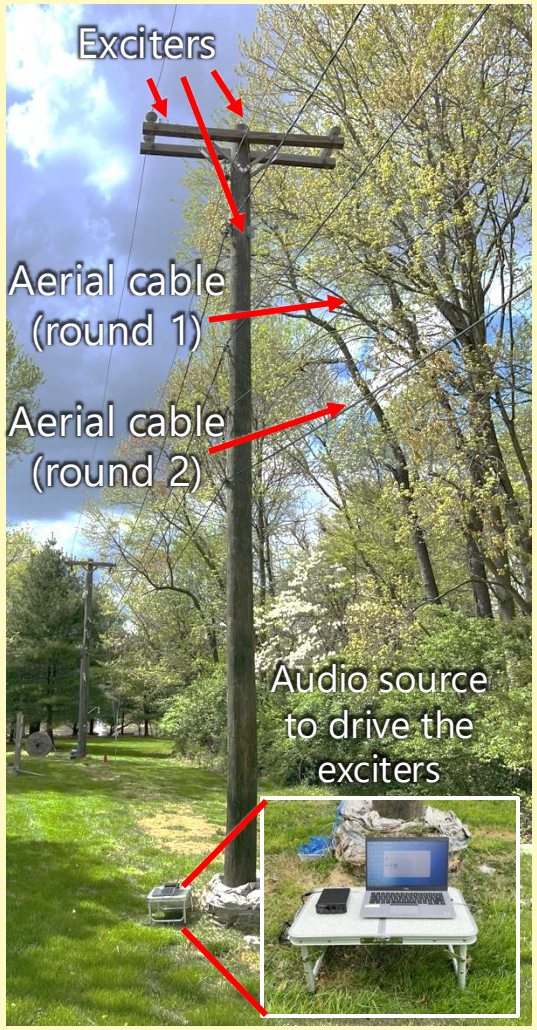
Pulse width: 40 ns

Pulse repetition rate: 20 kHz

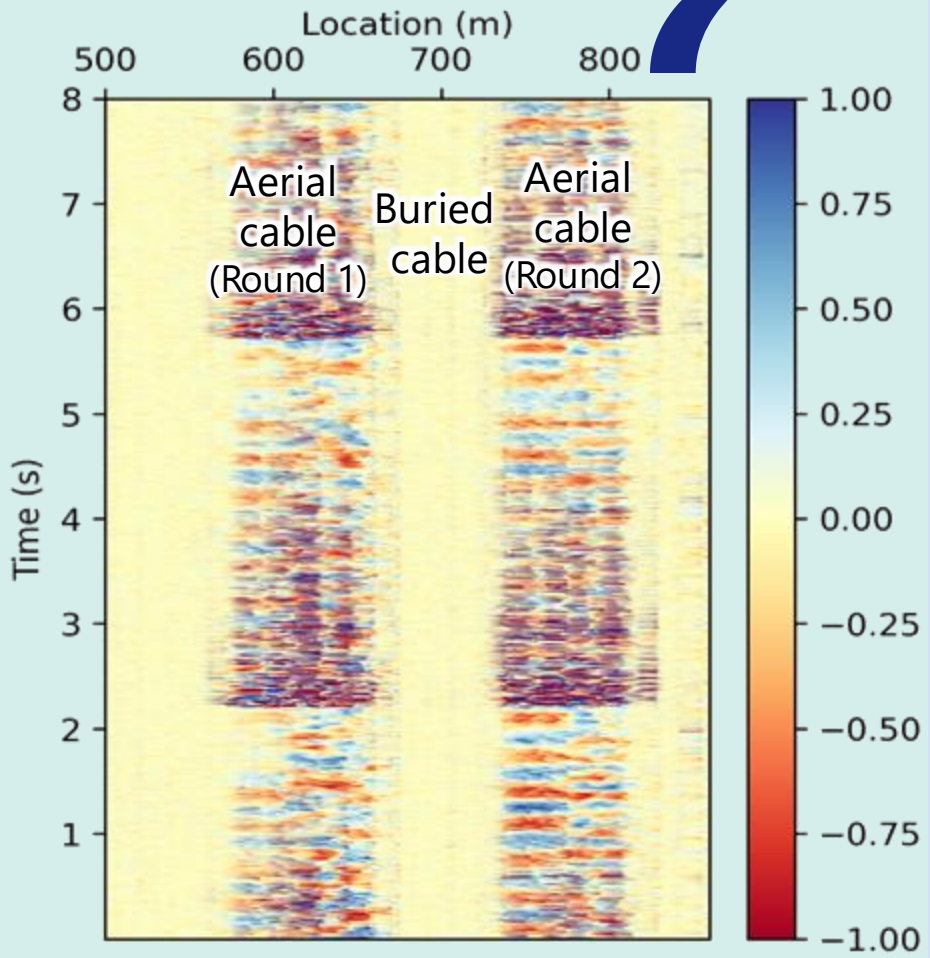
Gauge length: 4.08 m

Sound Emulation and Data Collection Scheme

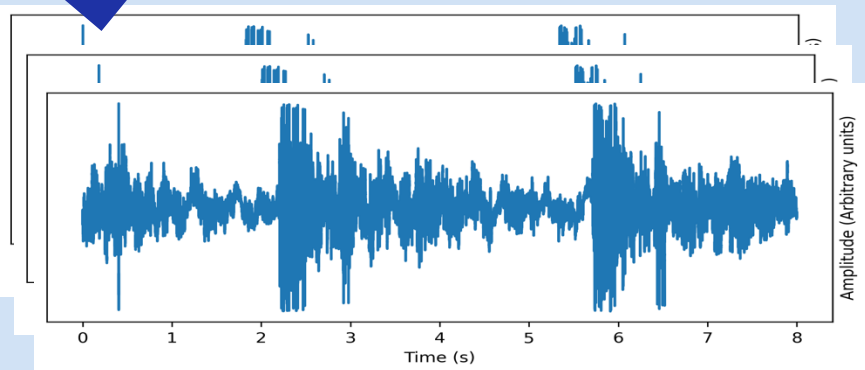
Sound emulation in field



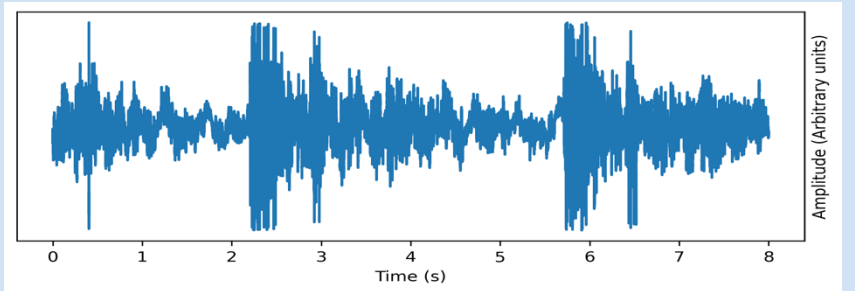
Captured DAS signal (2-D waterfall)



1-D time series data at each location



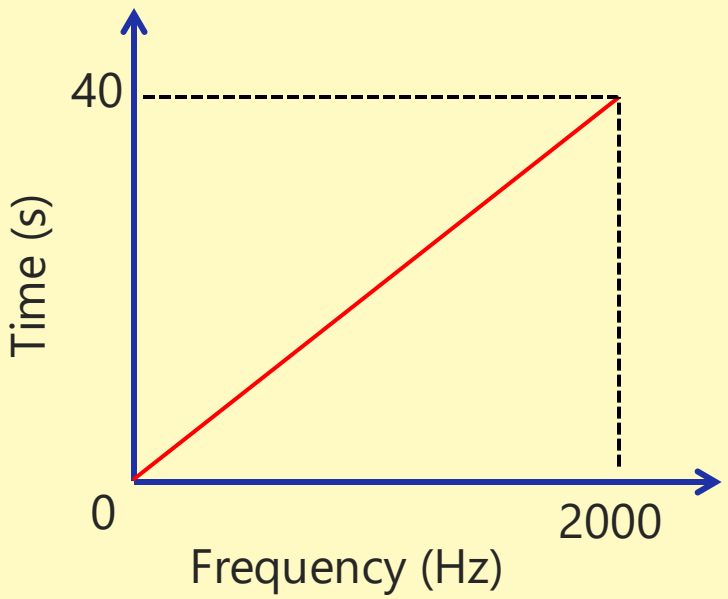
Pick the location of interest: pre-localized location closed to the sound source



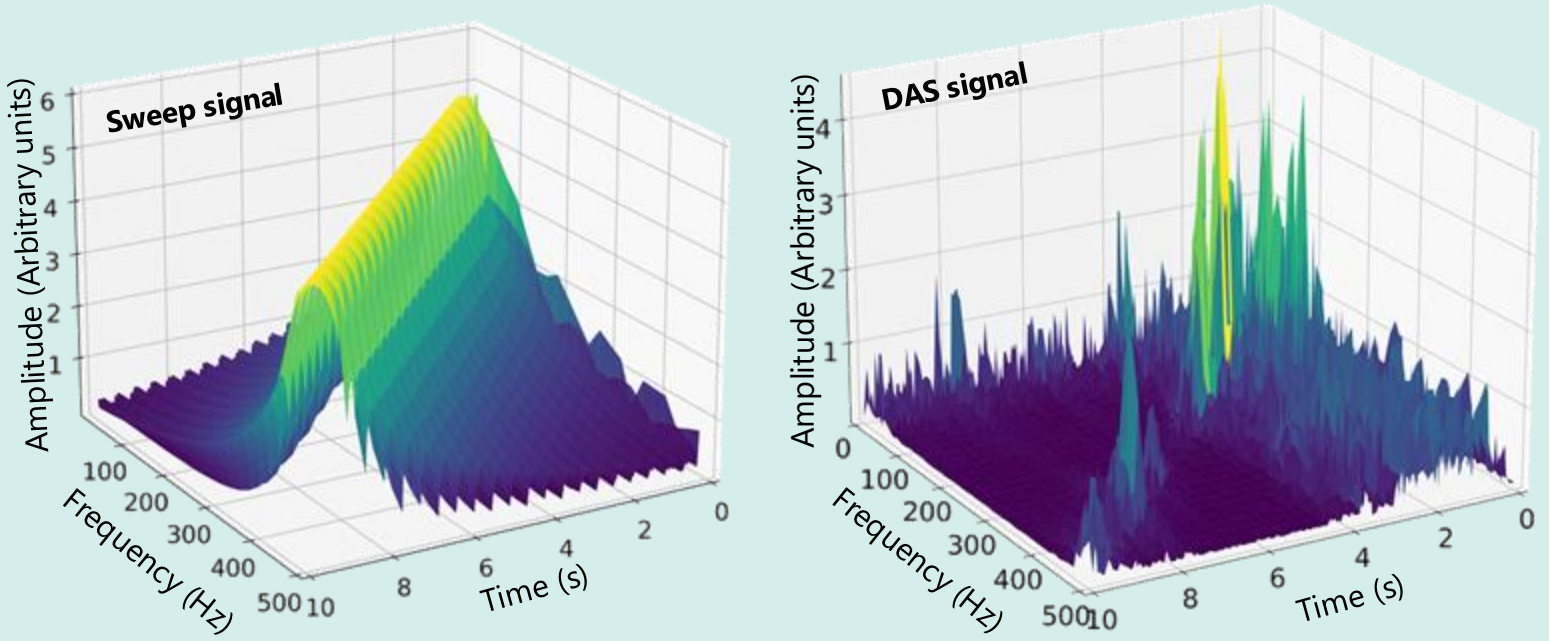
Frequency Response of the Exciter-Pole-Cable Structure

- Frequency sweep test: play sweep signal at exciter and record DAS signal from the cable

Sweep signal



STFT of sweep signal and recorded DAS signal at 0 – 500 Hz

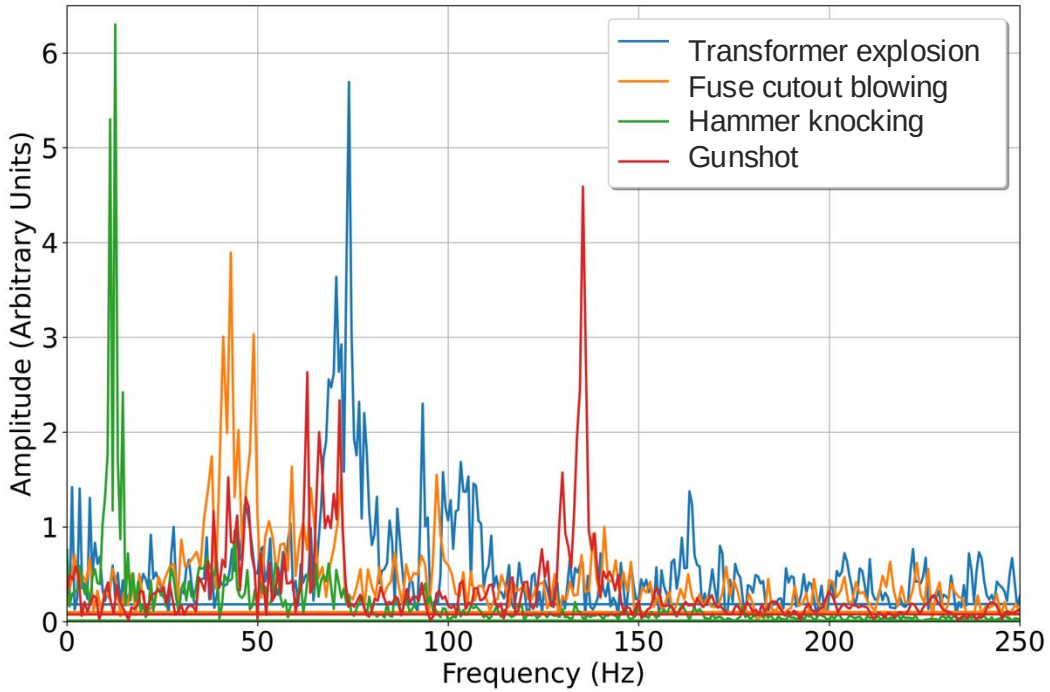


- Complex exciter-pole-cable system exhibits:
  - Strong attenuation at higher frequencies (>500 Hz)
  - Strong resonance (broadband/nonlinear response) at multiple frequencies from 0 to 150 Hz
  - Attenuation/Filtering effect at around 250 Hz

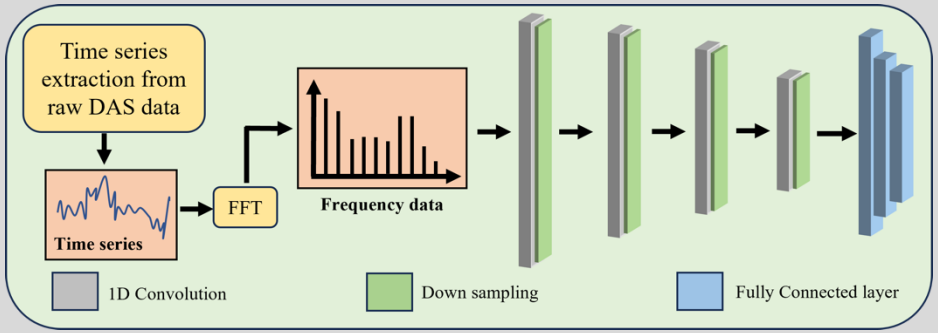
Fuse Cutout Blowing Detection from DAS signals

- Collect DAS data of four events
  - Fuse cutout blowing (exciter)
  - Transformer explosion (exciter)
  - Gunshot (exciter)
  - Pole knocking (hammer)

Fourier transform of time series DAS data

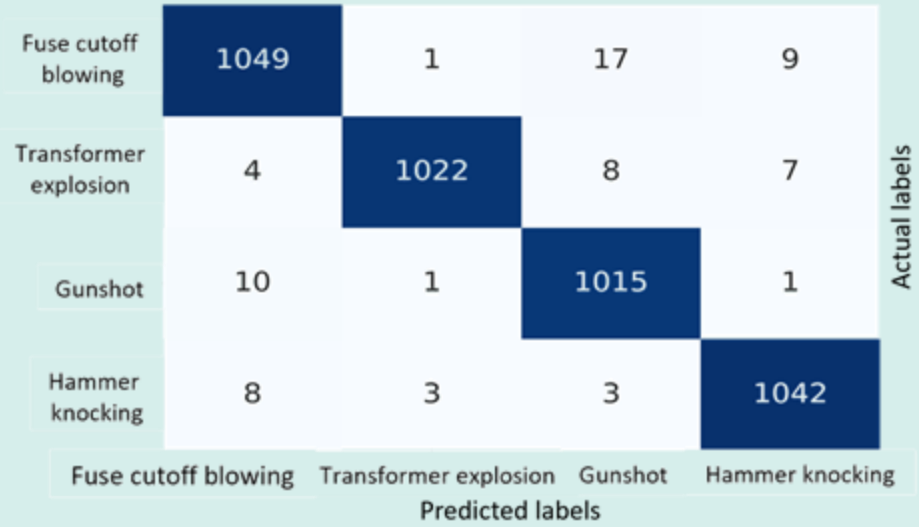


Proposed ML model for event recognition based on frequency-domain features of impulse events



Training dataset:
40,000 samples
Test dataset:
4,000 samples
Sample time length:
0.1 s

Model performance with 98%+ overall accuracy



Summary

- We demonstrated a remote fiber sensing solution for detecting fuse cut-out blowing events using existing telecom cables.
- Experimental investigation was done on a real-scale utility pole testbed with audio exciters to emulate various acoustic/vibration events.
- A DAS system connected to the aerial cable was used to collect vibration signals of the poles, which was processed and fed into a frequency-based learning model.
- The model achieved an accuracy of over 98% in identifying fuse cut-out blowing and other similar events.

This work showcases the potential to utilize large-scale telecom fiber networks for power outage sensing and fast restoration, benefiting both carriers and utility companies.

Acknowledgement

Special thanks to our collaborators at NREL.

This work was supported by the U.S. Department of Energy Solar Energy Technologies Office Agreement Number 40385.

NEC

NEC Laboratories **America**

Thank you!

Contact us:

www.nec-labs.com

ytian@nec-labs.com

Orchestrating a brighter world

NEC

NREL/PR-5D00-91455

This work was authored [in part] by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.