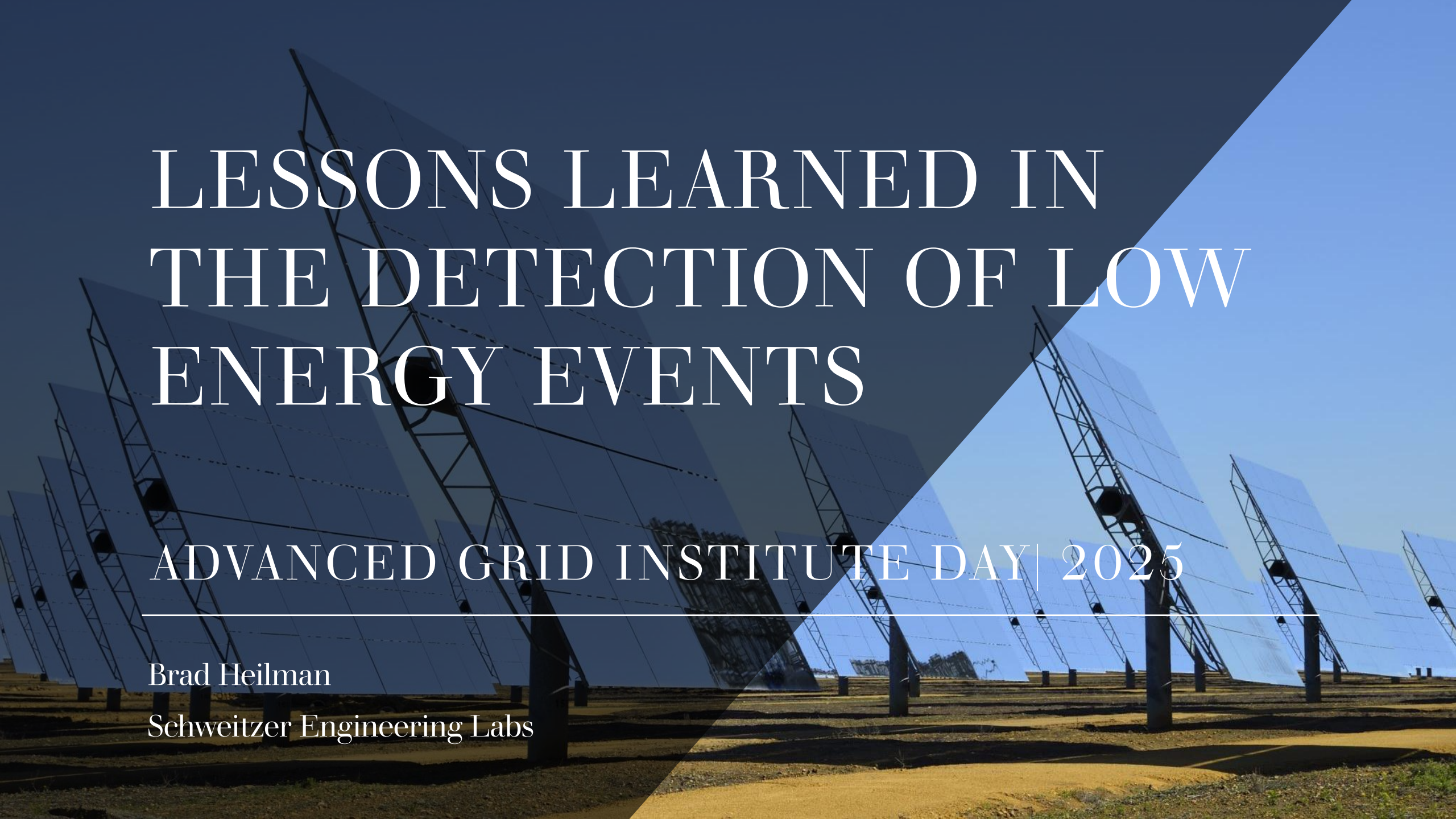

LESSONS LEARNED IN THE DETECTION OF LOW ENERGY EVENTS

ADVANCED GRID INSTITUTE DAY| 2025

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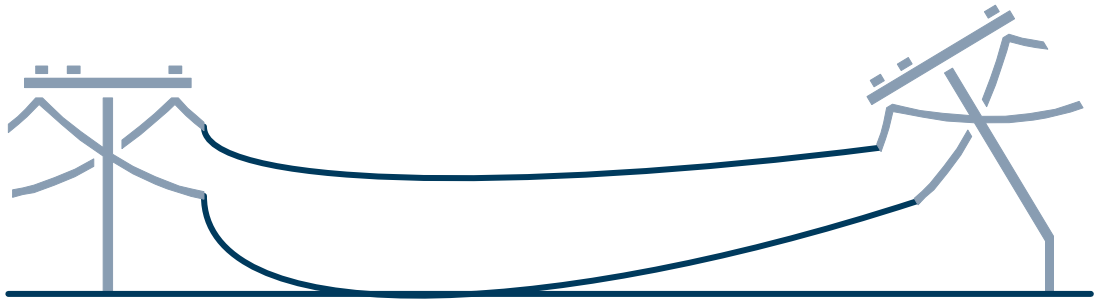
Schweitzer Engineering Labs

State of the Interconnect 2025
(wecc.org)

- Load
- Resources
- Transmission
- System Events
- Security
- Extreme natural events
  - Wildfire mitigation

Downed conductors

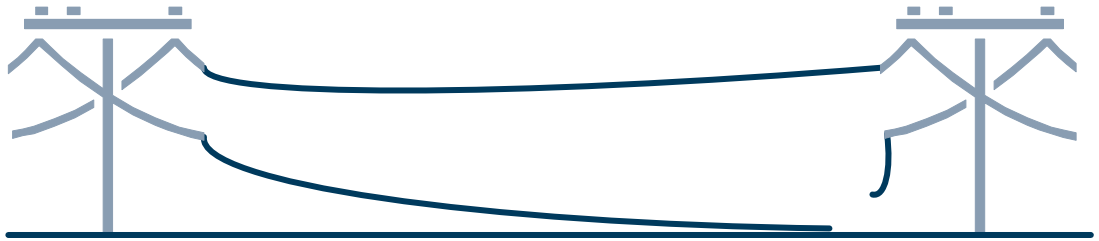
- Transmission – high voltage and balanced system allow traditional elements to operate
- Distribution – low voltage and imbalanced system makes detection more challenging (special algorithms are used for detection)



Downed conductor

Broken conductors

- Transmission – high voltage and line length allow charging current to be used for detection
- Distribution – open phase detection using wide-area measurements can be used for detection



Broken downed conductor

Vegetation encroachment

- Begins with tree contact causing high-resistance low current (precursor event)
- Can eventually develop into low resistance fault
- It’s possible to detect precursor event and perform maintenance before permanent fault develops

Insulator contamination

- Birds
- Chemicals

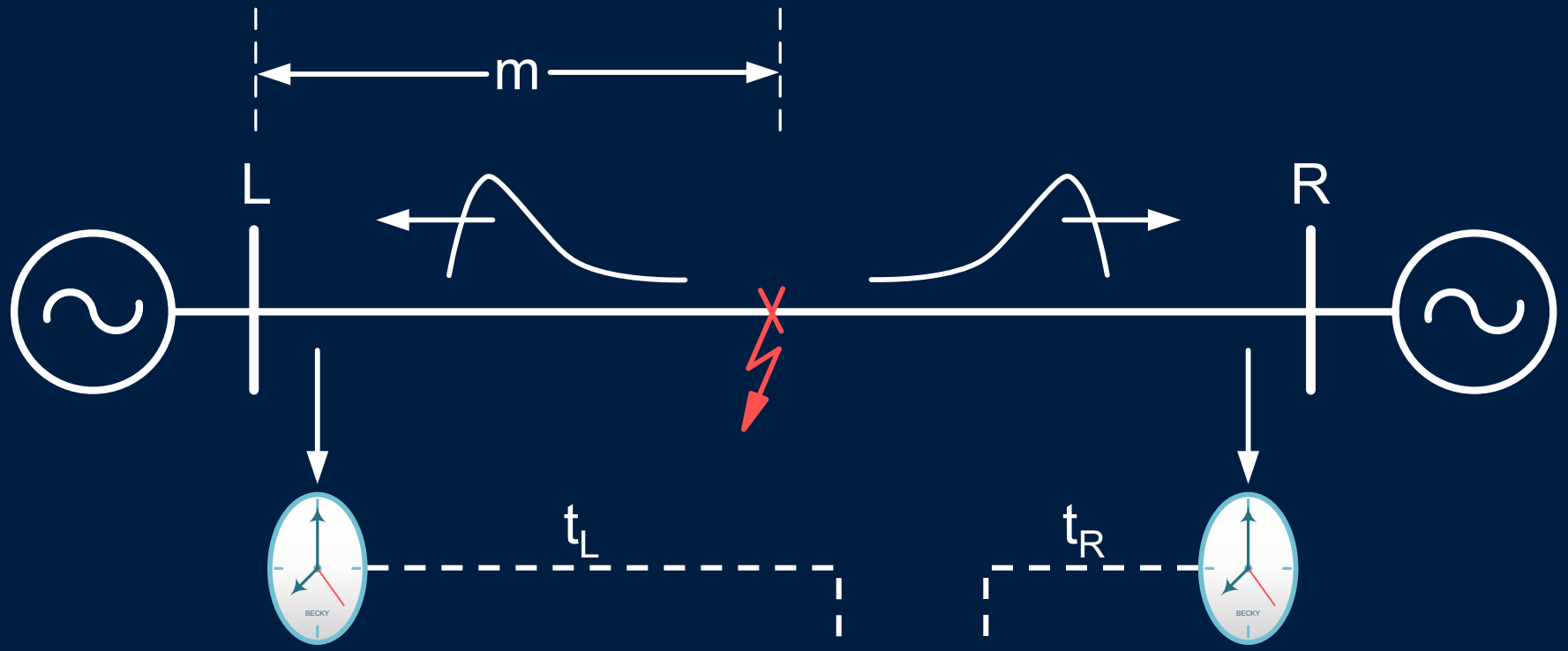
Low-energy precursors can be used to find trouble areas before permanent fault develops

Photo courtesy of BPA, 2017

Literature Review: Transmission

- Solutions
  - Traveling waves
  - Line monitor
  - “No Go” zones
  - Broken Conductor Detection

Faults and Disturbances Launch Traveling Waves



$$m = \frac{1}{2}\left[\ell + (t_L - t_R)v\right]$$

Application considerations

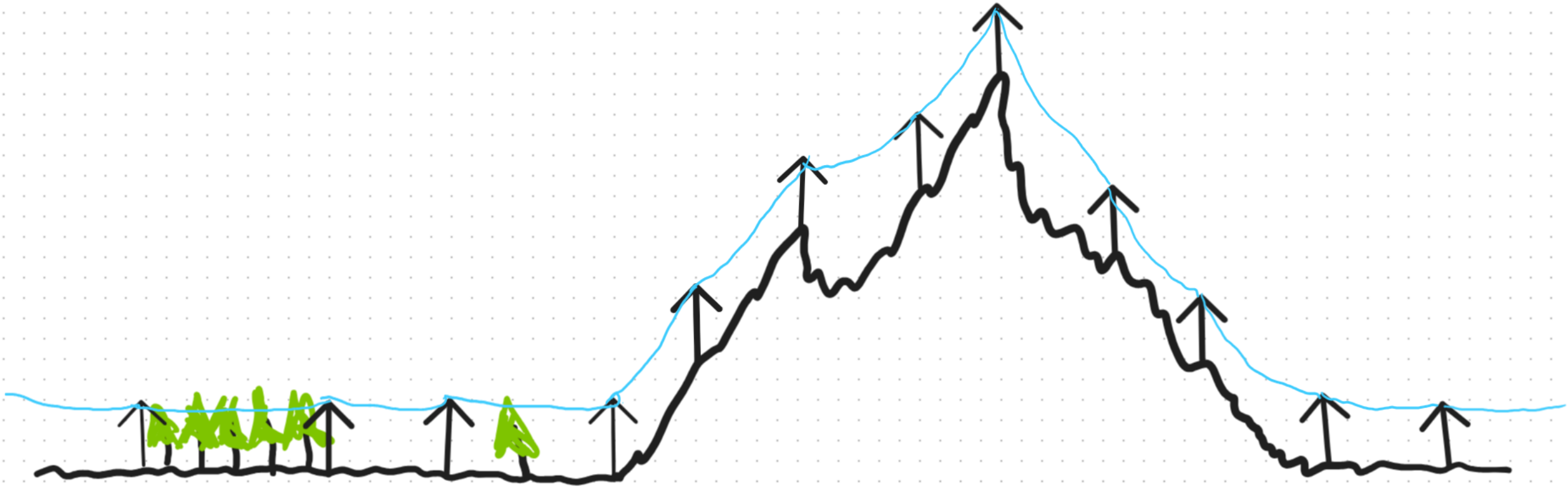
- Minimum line lengths of approximately 10 miles (16 km)
  - The longer the line the better
- Two terminal line
  - No more than two taps
- Line PTs
- High-speed data retrieval and visualization software

Fault locator

Some faults are easy to find

Flashed insulators are hard to find

Line monitor



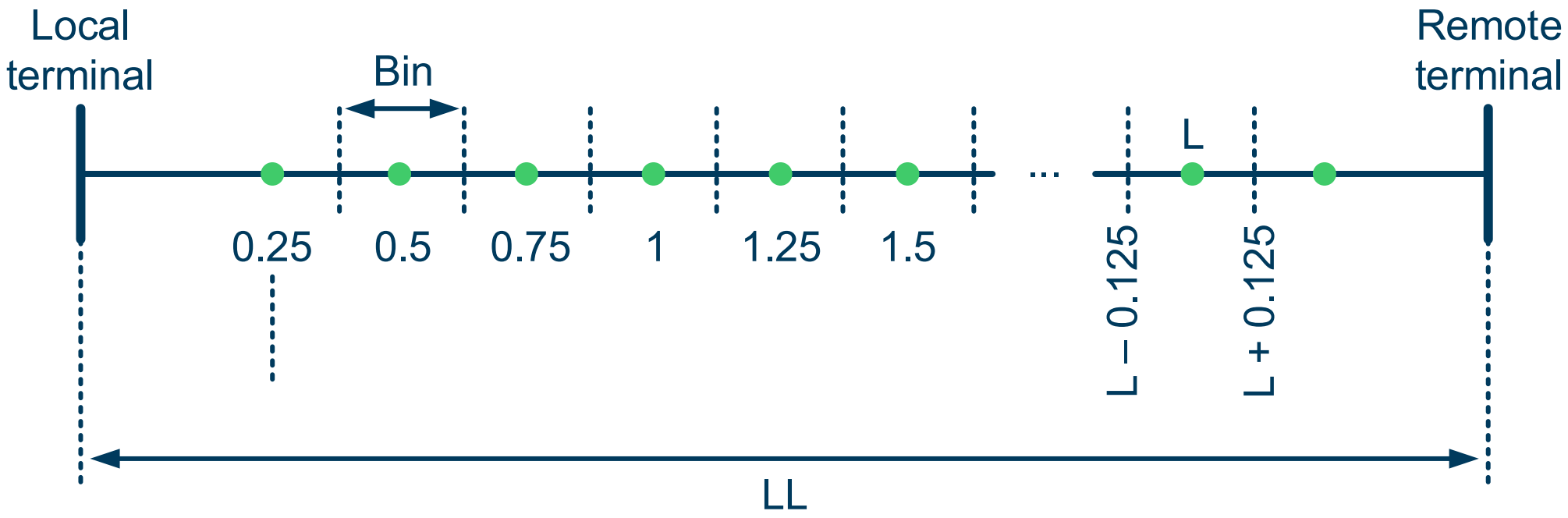
Rough approximation of transmission line profile

Line monitor counts low-energy and fault events and asserts alarm

- Trigger double-ended TW fault locator, even if no trip occurs
- Calculate event location if no trip occurs, and calculate fault location if trip occurs
- Tabulate event and/or fault locations over time in 0.25-mile or kilometer bins
- Assert alarm or trip on high bin counts

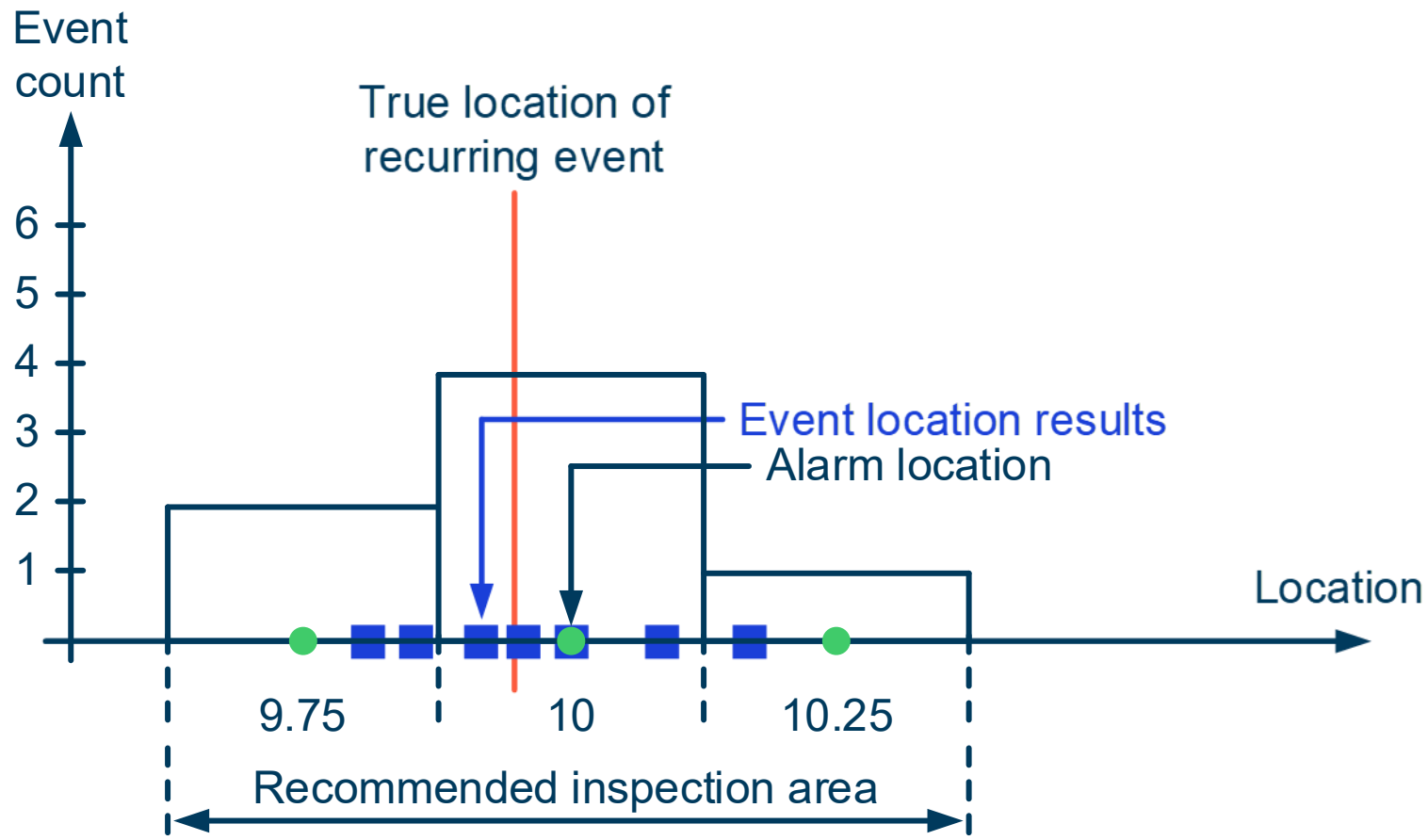
Principle of operation

LINE DIVIDED INTO BINS FOR HIGH & LOW ENERGY EVENT COUNTING



Principle of operation

ASSERTS ALARM ON SUM OF COUNTS IN THREE ADJACENT BINS



Improve operations with line monitoring

Vegetation encroachment
Trim vegetation to prevent faults

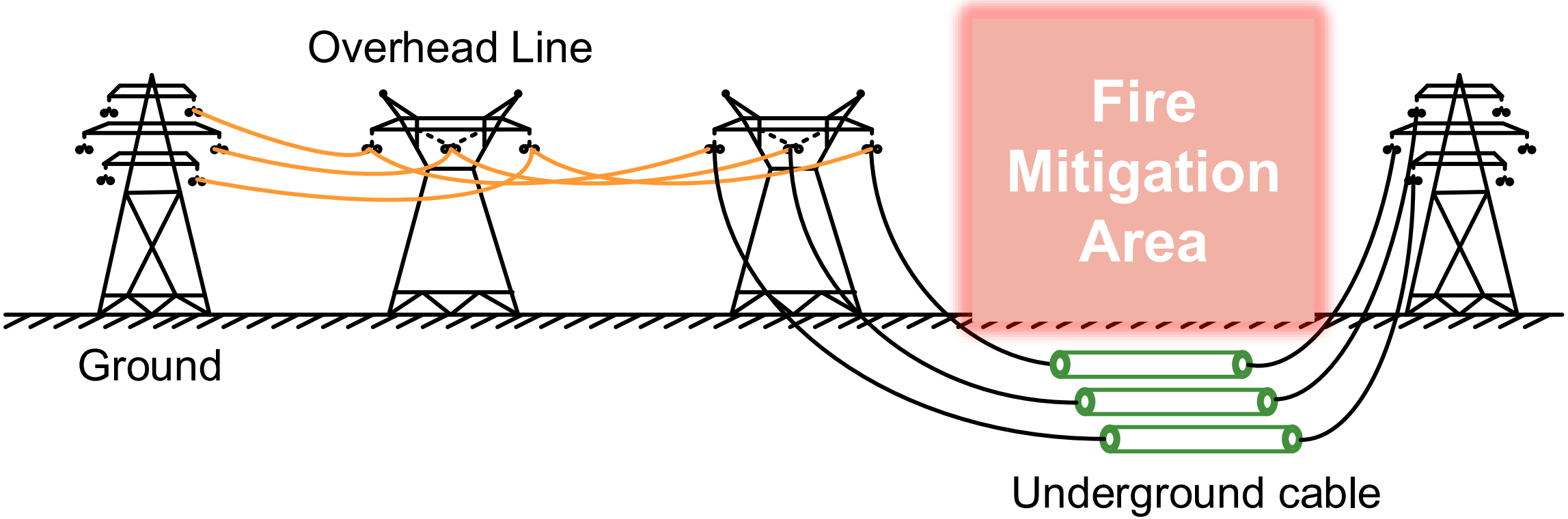
Failing insulators
Replace to reduce fault count

Dirty insulators
Wash to prevent faults

Nonelectrical brush fires
Gain awareness, determine sequence

Autoreclose cancel logic

Fault locating is critical



Literature Review: Distribution

- Solutions
  - High impedance fault detection
  - Broken Conductor Detection
  - Wireless solutions

Distribution

High-impedance fault detection

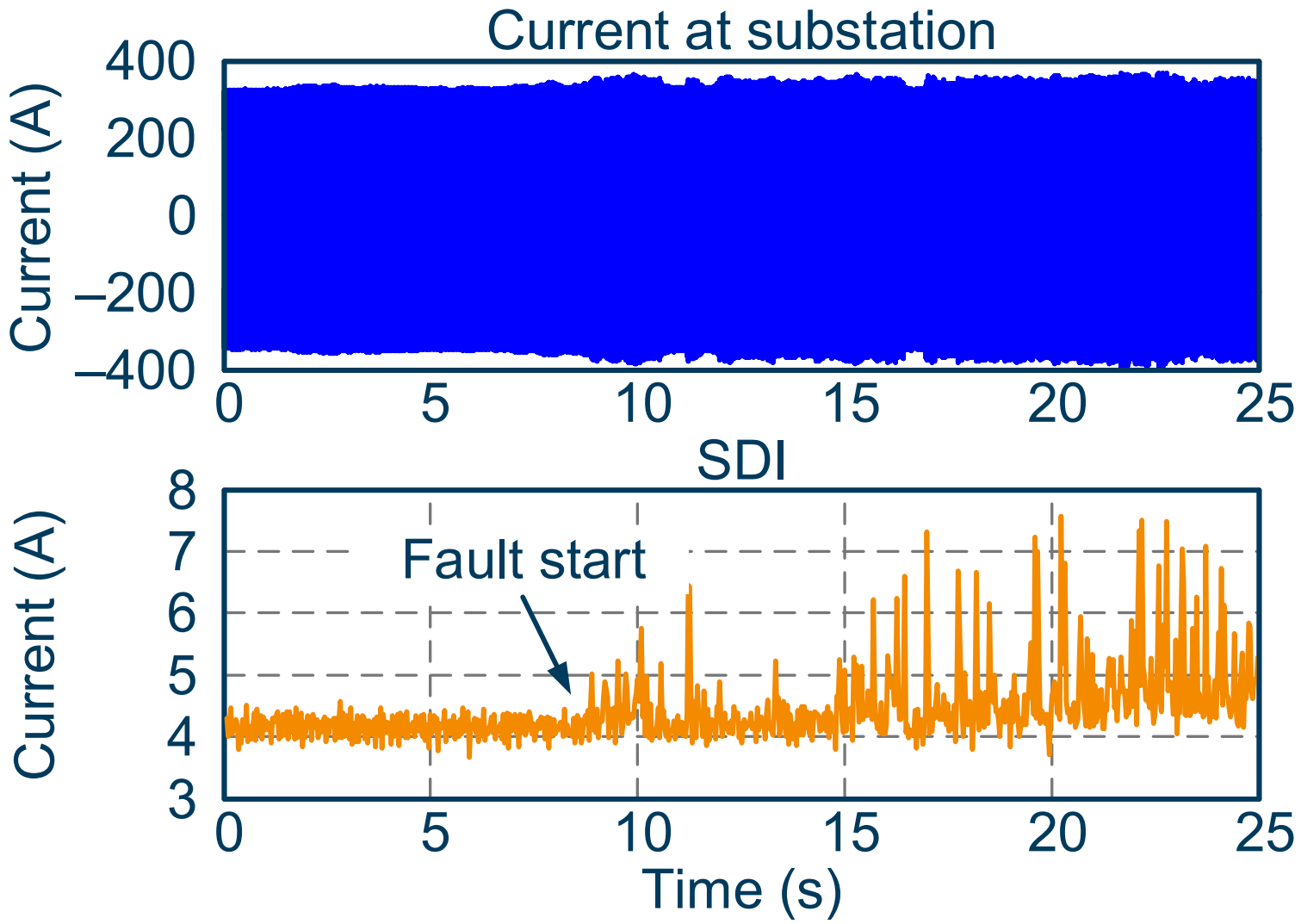
System grounding affects sensitivity

- Grounded systems allow large standing unbalance and reduce sensitivity of traditional elements
  - Adaptively tune unbalance
  - Identify HIF signatures in current waveform
- Resistance grounded and ungrounded systems allow for small standing unbalance and high sensitivity
  - Core balance CT
  - Sensitive ground directional elements

Grounded distribution system

High-impedance fault detection

Arc Sense Technology



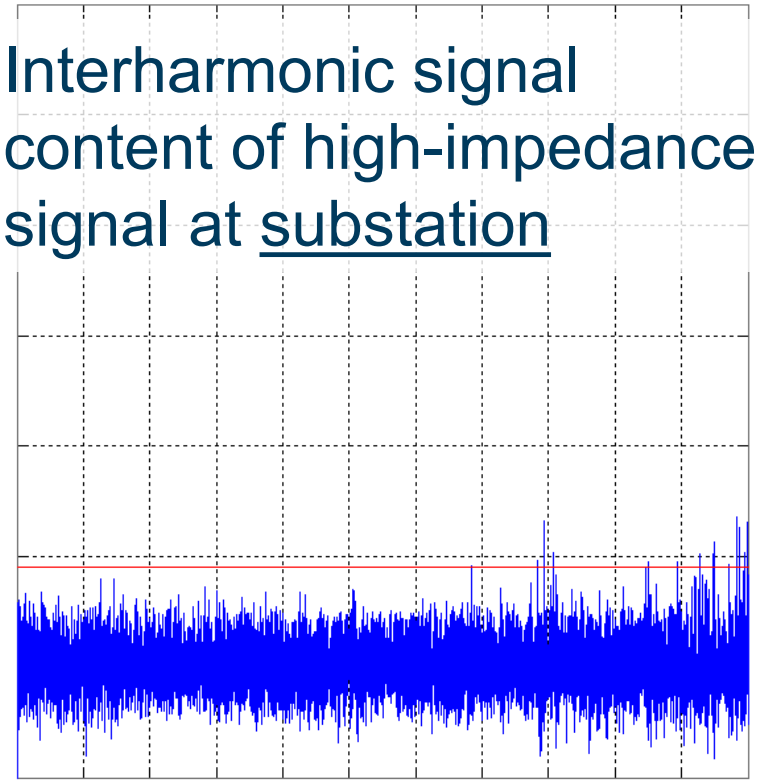
- Informative quantity that reveals HIF signatures and nothing else
- Stable average
- Adaptive feature that tunes out feeder ambient characteristics
- Memory and decision scheme to declare arcing event
- Self-learning of ambient conditions

Adaptive tuning

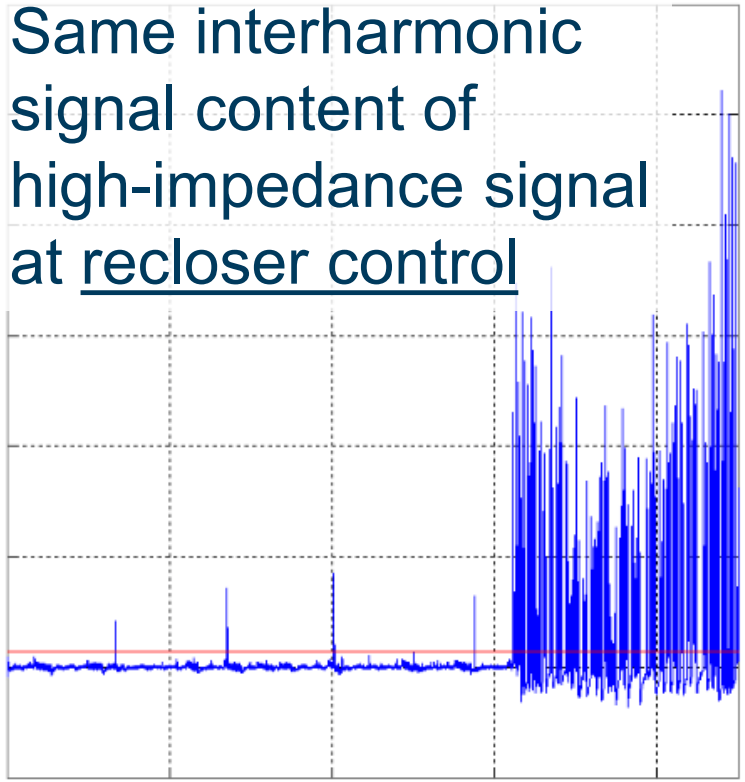
- Different feeder load has different impact on detection
- It is impractical for user to characterize these impacts
- Adaptive tuning does the following
  - Characterizes SDI on individual feeder load
  - Adapts to feeder ambient noise
  - Increases fault-detection security

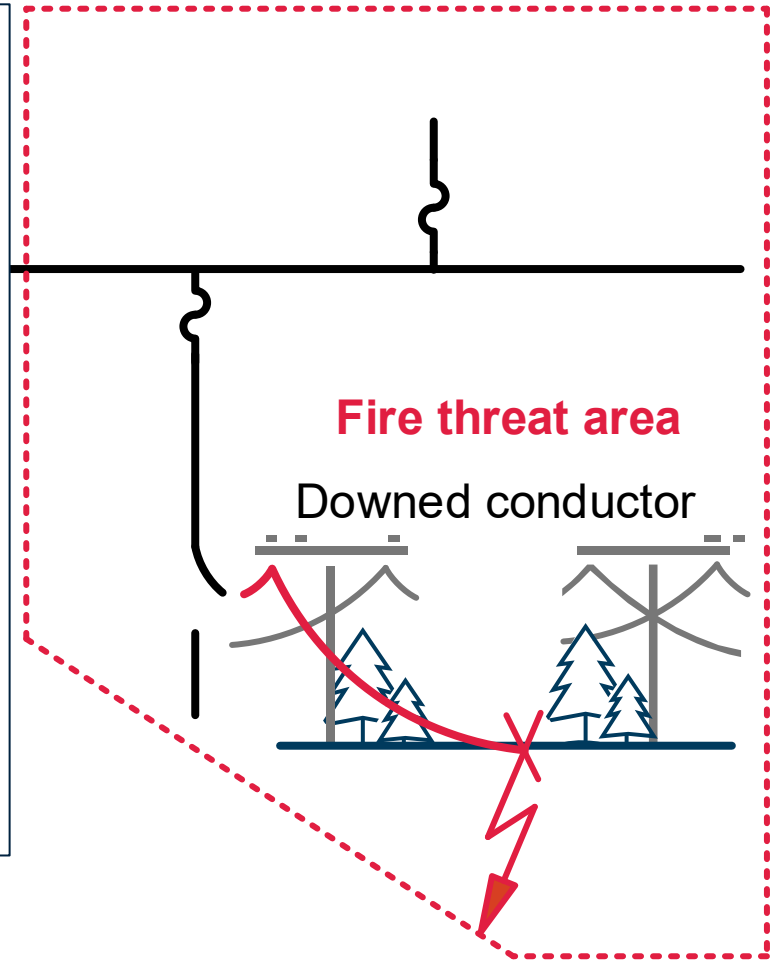
Apply high impedance fault detection in relays and recloser controls

Interharmonic signal content of high-impedance signal at substation



Same interharmonic signal content of high-impedance signal at recloser control

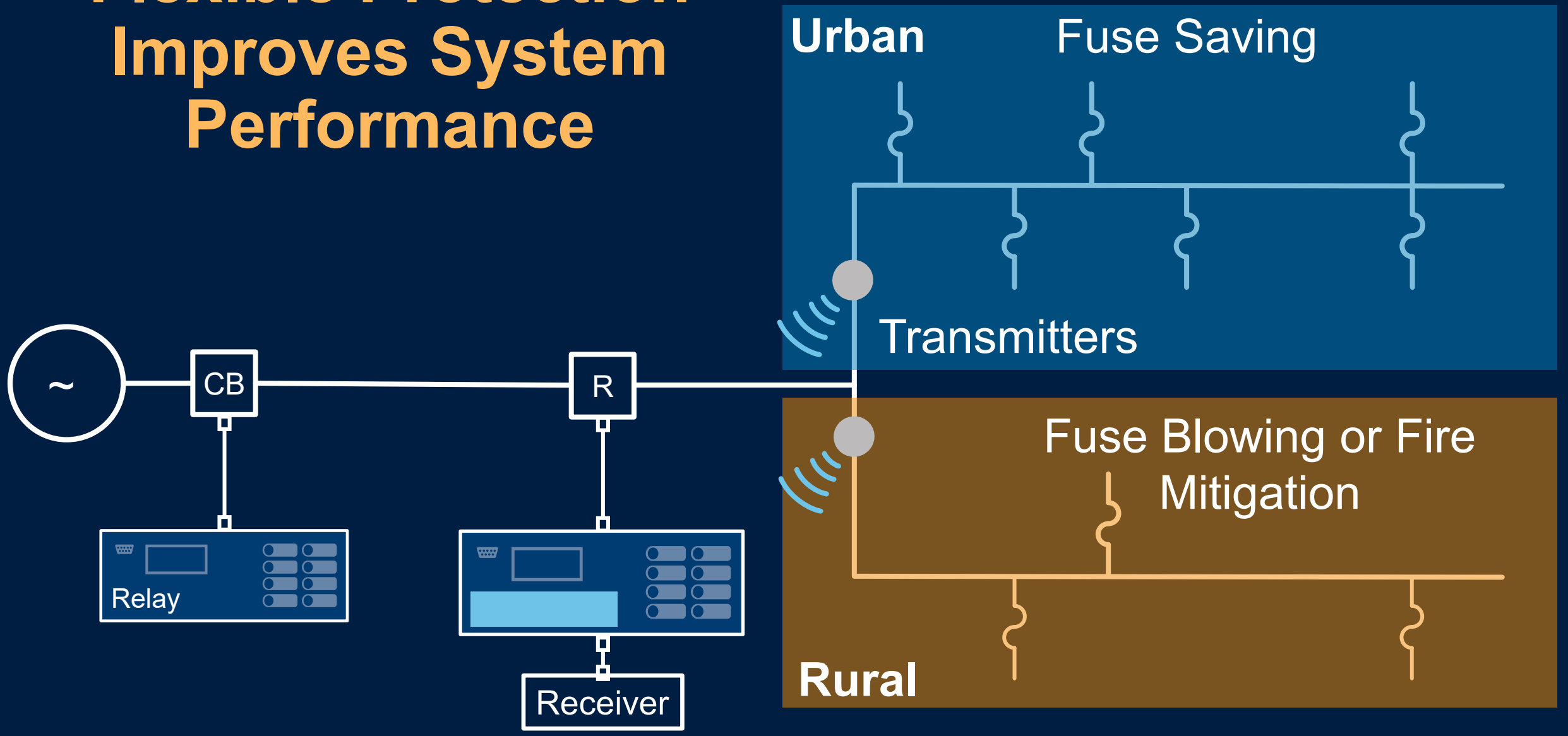




It is not possible to detect 100% of HIFs

High-impedance surface	Detection		
	Good	Better	Best
Earth			
Tree			
Gravel			
Concrete			
Sand			

Flexible Protection Improves System Performance



Questions?