SAFEGRID

Technology Company
- Reliability solutions
- Transmission and distribution grids

Innovative Solutions for Faults
- Detection, Location, Prediction

US Utility Customers
- 18 Cooperatives
- 9 Municipals
- 6 Investor Owned

Partner Network

jr
Jake Rudisill Associates

Collaboration Acquisition

G&W Electric
Engineered to order. Built to last.
SAFEGRID

Based in Finland
Established 2019
US focus starting 2023

30
Employees

	Global	United States
Customers	80+	33
Sensors Installed	2500+	800+

Agenda

- Why focus on Grid Reliability?
- Why new tools are needed for Fault Location?
- Why Fault Prediction is important?

- Considerations for traditional fault location tools
- New technology, approaches and tools
- Use cases and examples

Agenda

Why securing the power system is important

Reliable power supply more important than ever

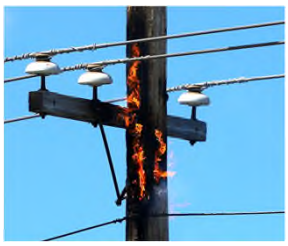
Global electricity demand is projected to grow at 2.1%
per year until 2040, increasing by over 50% in total

Climate change and climate caused outages

Wildfires create up to 10 percent of global CO2 emissions. Detecting fire-inducing faults such as trees touching power lines enables wildfire prevention

Distributed generation and renewables

Increasing penetration of renewables changes grid dynamics and makes it de-centralized. Improved monitoring is needed



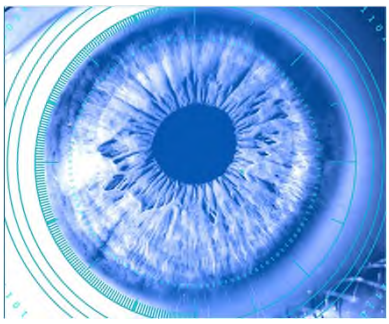
Hard-to-find faults needs a solution

Traditional methods can't find high-impedance earth faults and intermittent earth faults. A new solution is needed

Grid reliability is crucial for the on-going energy transition

Key elements of Safegrid's IGS

Application above 1 kV



Improve grid visibility

Detect faults other solutions cannot
High impedance faults
Improve SAIDI

Locate faults at 100 meter accuracy

Reduce restoration time
Lower repair cost
Improve SAIDI

Predict faults

Identify precursory events
Avoid unplanned outage
Improve SAIDI & SAIFI

Fault Location Solutions

Indicators

Flags

Blinking lights

Visual Enhancement for patrolling

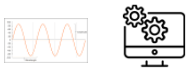
Communicating Sensors

Fault current passage

Basic data transfer

Logical Fault location

Accuracy is based on spacing - Patrol



Advanced Sensors

Communications

Advanced data

Impedance Model – Distance to Fault

Multiple potential locations

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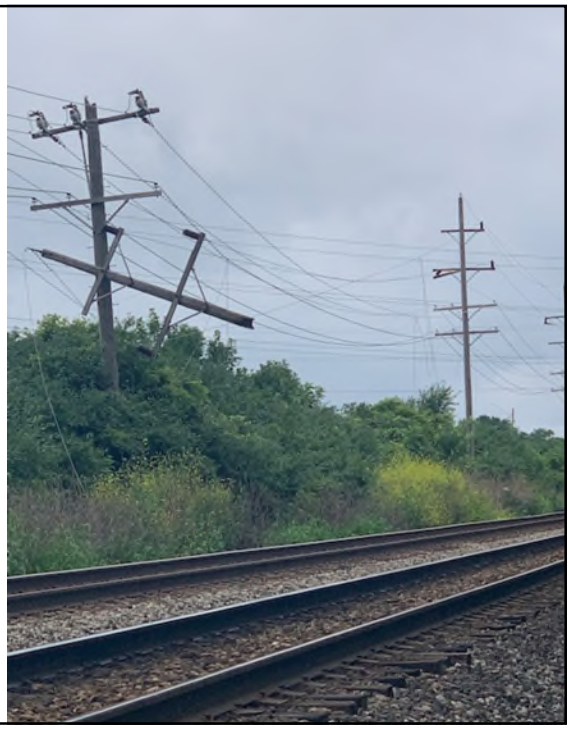
Safegrid Technology – A unique approach to fault location and prediction

Fault Passage Indicators

- Pros
  - Patrol Enhancement
  - Can be relatively inexpensive/simple
  - Can have blinking lights to aid in the dark
  - Can communicate to SCADA
  - Solutions for both OH and UG applications
- Cons
  - Patrol past a point
  - Time over current – only sees certain problems
  - Voltage limitations
  - Can cause conductor issues – clamps, sag, ice
  - Manual reset F/I's sometimes do not get restored
  - Power harvesting models can have battery issues with low power flow
  - Radio comms are sometimes out of scan (900Mhz)

Power System & Impedance Models

- Pros
  - Provides accurate distance to fault
  - Work well in Transmission/Sub-Transmission lines
  - Can utilize data from relays, PQ meters, DFRs
- Cons
  - Requires an accurate power system model
  - Requires tools, experts and time to calculate distance
  - Can produce multiple fault locations in distribution circuits
  - Calculations need to be updated for changes to circuit



Newer Grid Monitoring Technologies

- Monitors mechanical parameters
- Quick to install
- Battery/Solar powered
- Works at any voltage

- No electrical information
- Requires devices every 2-3 poles

- Monitors electrical field
- Partial discharge
- Predictive fault capability

- Additional cross arm required
- Installation is engineered solution
- Data analysis - false positives

- Easy and fast installation
- No contact with conductors
- Works at any voltage
- Precise fault location - 100 meters
- Predictive fault analysis

Safegrid Approach

System Focus

Communications
Data collection
Cloud based software solutions
System integration

Technology

Traveling Wave technology
Current waveforms
Fast current transients at 1Mhz
Location to +/- 100 yards

Innovative Sensors

Grayhawk
Grayfox

Safegrid Technology – A unique approach to fault location and prediction

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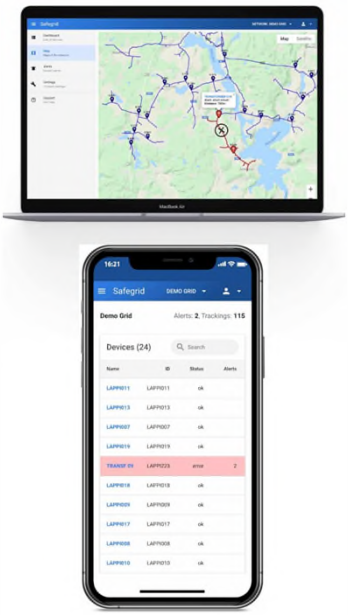
System



Grid Guardian

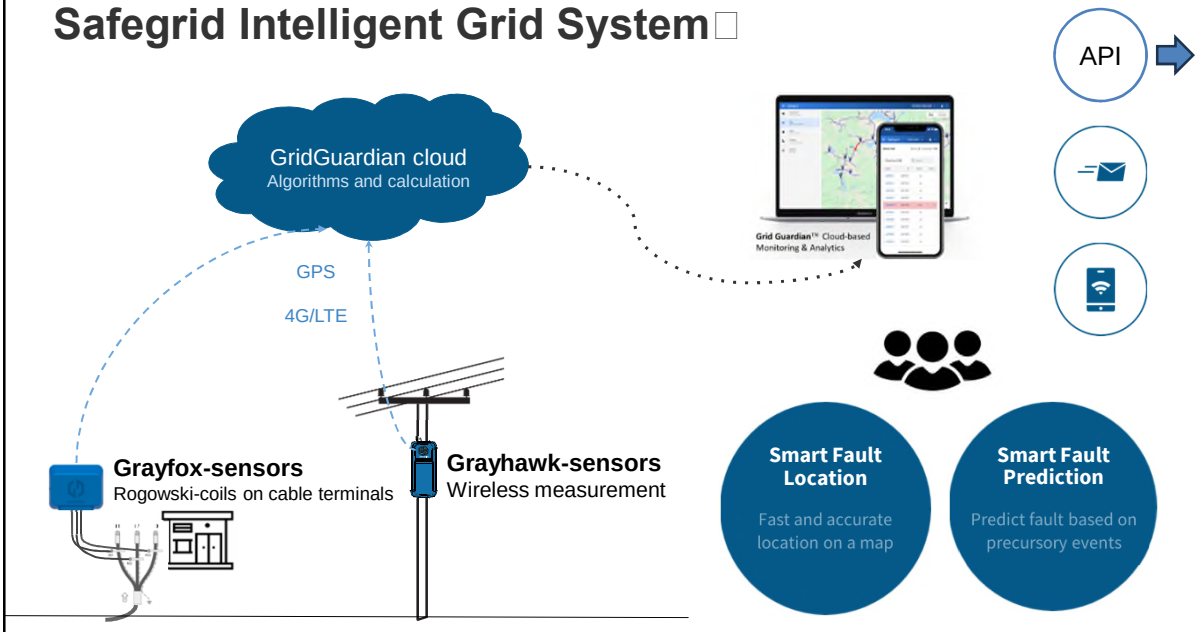
- Intuitive event and sensor management
- Visual GIS based real-time monitoring

- Cloud based monitoring and analytics
- ISO 27001 Certified
- Browser and mobile user interfaces
- Stand alone tool for analysis and integrated with other system

- Smart Fault Location
- Smart Fault Prediction

LOCATE. PREDICT. PREVENT.

Safegrid Intelligent Grid System



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Sensors

Monitoring the Grid

Transmission

Substation

Overhead Distribution

Underground Distribution

A simple and scalable solution for medium and high voltage overhead and underground lines

Safegrid's IGS Sensor main unit

All Safegrid sensors are based on the main unit. Different variants are created by adding accessories to package with the main unit.

- **IP Class: IP65**
- **Sampling frequency: form 2 kHz to 1.2 MHz**
- **Battery: Li, 24-hour backup, operating temperature from -35 C up to 75 C.**
- **Comms: 2G & 4G LTE-M, SIM card provided by Safegrid. Multi-network - the device selects the cellular network with the best signal**
- **Time & location synchronisation: GPS & Galileo**

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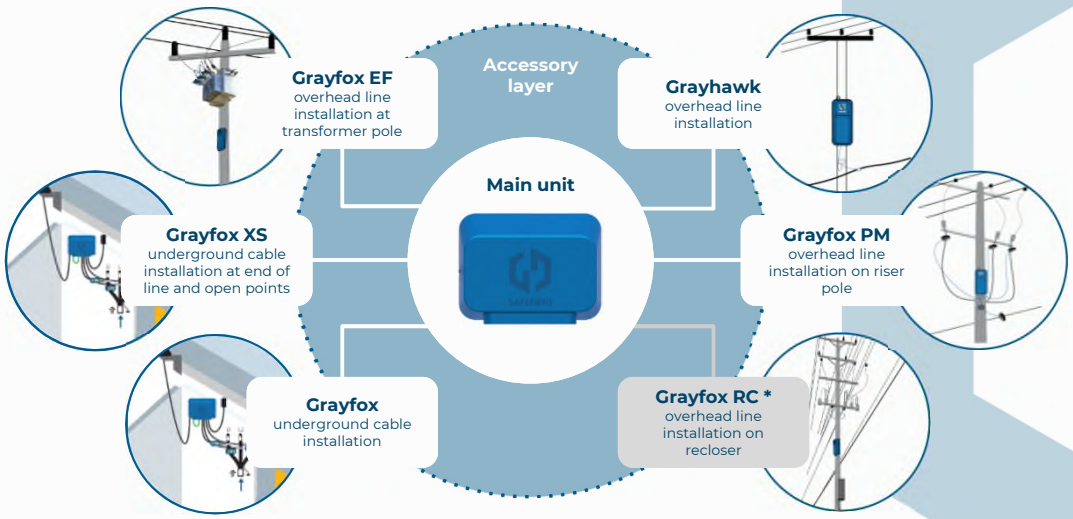
Sensor main unit & variants



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*supplied to selected projects only

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Grayhawk

Overhead lines

Deployment in less than 30 minutes

Senses magnetic fields
Detects transients

- **No physical connection to the line**
- **No outage needed for deployment**
- **Simple & accurate, sampling at 1 MHz**
- **Location and time sync by GPS**
- **Cellular communication to Grid Guardian**
- **IP65 rated**
- **Power 100 to 240 V DC or AC. Solar option 12 to 24 V DC. 24 hour battery**
- **Compatible with all grounding types and most pole configurations**

Innovative design for safe, simple and fast deployment

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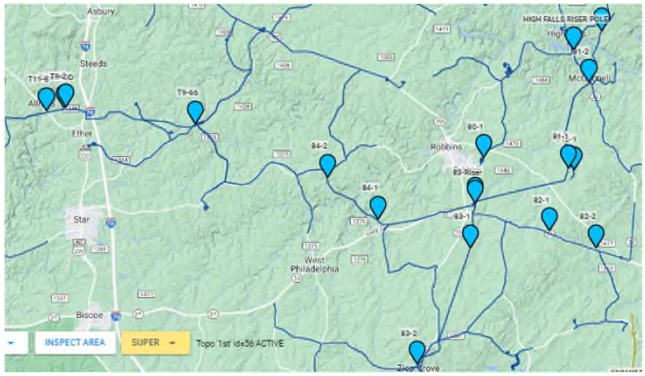
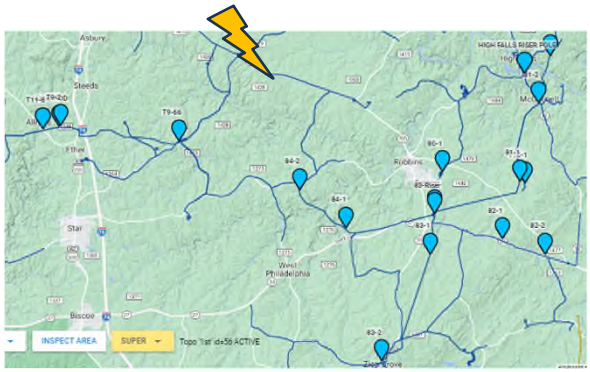
Technology

Distributed Sensor Network



- **Import topology from GIS system**
- **No impedance model calculations**
- **Sensors strategically placed to provide maximum coverage**
- **Transmission 4 to 6 miles**
- **Distribution – System Complexity - 2 to 3 miles**
- **Tools for evaluating locations – planning pins**
- **Based on distance, number of taps, branches**

Sensors Collect Data

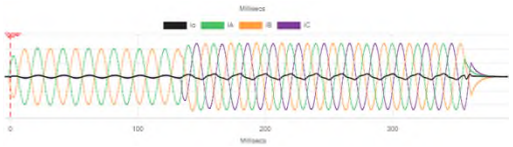


Trigger on current

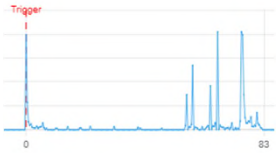
Or

Trigger on transient

Current Waveshape / Oscillography
2.4 KHz



Fast Transient Signals
1 MHz



Data Analysis

Process Data

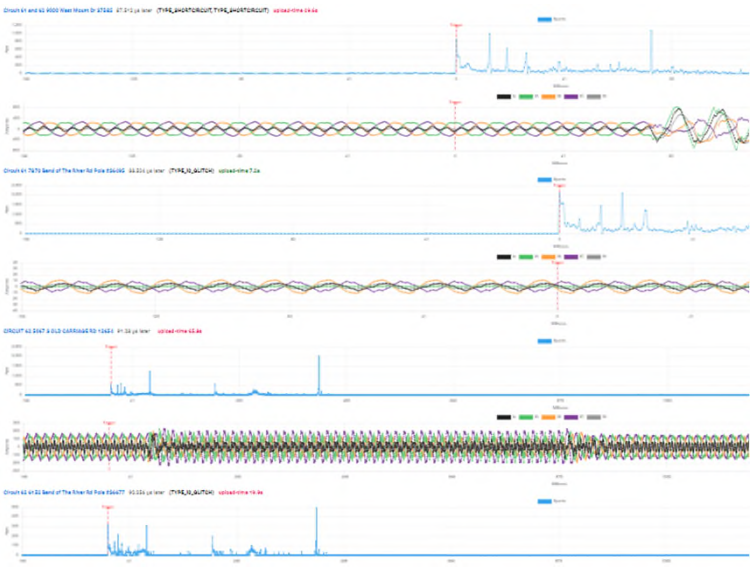
Sensors detect transient signals that trigger data recordings and data is uploaded to GridGuardian

Align Data

Group events & reclosing actions

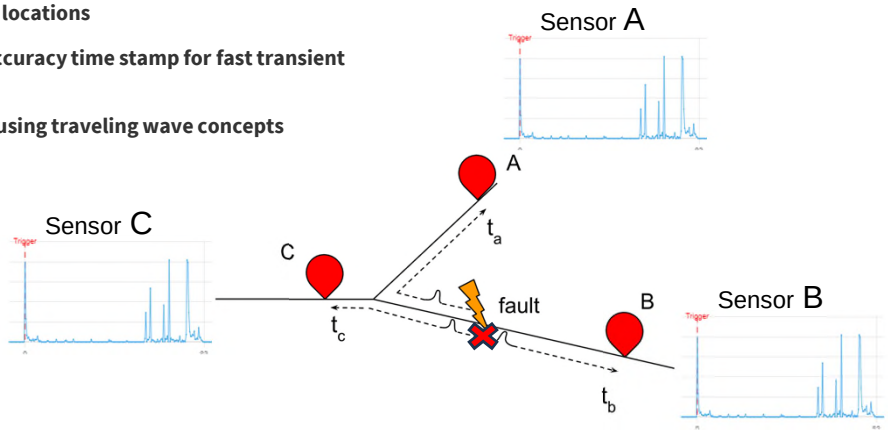
GPS location & timestamp

Align data in time



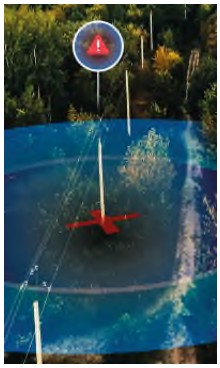
Location Algorithm

- **Fast Transient detected at sensors**
- **Topology defines distances between sensors**
- **GPS provides sensor locations**
- **GPS provides high accuracy time stamp for fast transient**
- **Location calculated using traveling wave concepts**



Classification Algorithm

Fault



Short Circuit
Action Required
Email, Text

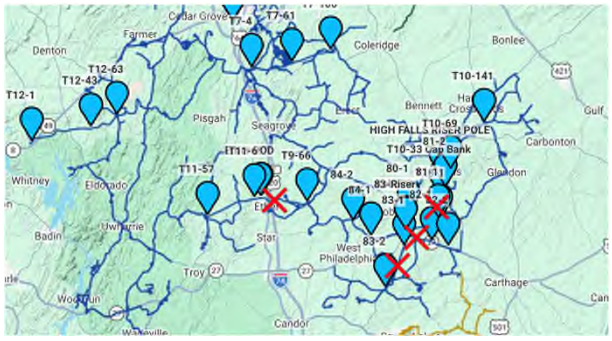
Classification

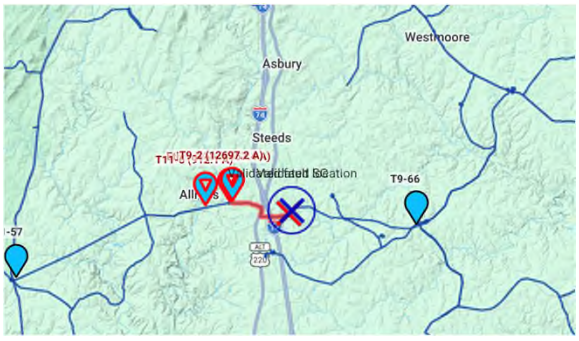
GridGuardian analyses data and classifies events by type and severity by correlating data from participating sensors

Predictive

No immediate action
Pattern recognition
Requires multiple data points

Smart Fault Location





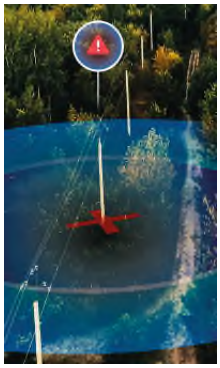
Alerts (5)

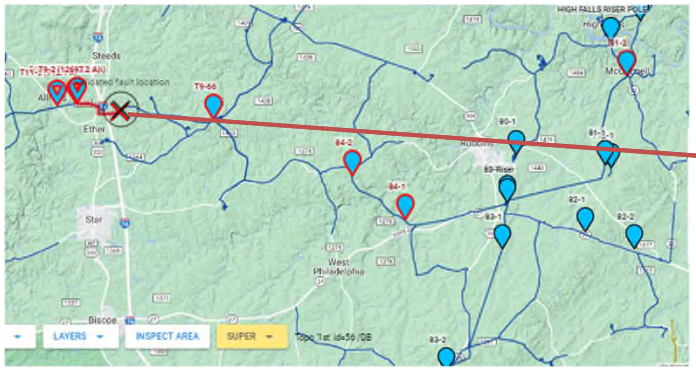
Search

Device	Type	Fault Current	Level	Location	Time (GMT-5)	Actions
T9-2, T11-6, Ether POD	SHORTCIRCUIT - LINE TRIPPED, RECLOSE, PHASES_C	5474.3 A	CRIT	No location available (reclosing on fault) Downstream from: Ether POD, T11-6, T9-2	Nov 29 2023, Wed, 4:45:58.434 AM	
T9-2, T11-6, Ether POD	SHORTCIRCUIT - LINE TRIPPED, PHASES_C	5457.4 A	CRIT	1.458 mi from T9-2, 2.893 mi from T9-66 Downstream from: Ether POD, T11-6, T9-2	Nov 29 2023, Wed, 4:45:52.909 AM	
Robbins	SHORTCIRCUIT - PHASES_AN	2740.5 A	CRIT	1.371 mi from 83-Riser, 1.400 mi from 82-1 Downstream from: Robbins	Nov 09 2023, Thu, 11:49:48.436 AM	
83-Riser, 83-1, Robbins	SHORTCIRCUIT - PHASES_BN	909.9 A	CRIT	1.632 mi from 83-1, 2.402 mi from 83-2 Downstream from: 83-1, 83-Riser, Robbins	Nov 03 2023, Fri, 7:09:26.576 PM	
81-1, Robbins	SHORTCIRCUIT - PHASES_B	1004.4 A	CRIT	1.742 mi from 81-2, 5.832 mi from 80-1 Downstream from: 81-1, Robbins	Nov 03 2023, Fri, 4:41:37.114 AM	

Records per page: 50 1-5 of 5

Smart Fault Location





Actionable Information - Email or Text Alert

Type	Location	Time
SHORTCIRCUIT - PHASES_AN Fault current 2740.5A	2.207 km from 83-Riser, 2.253 km from 82-1 Downstream from: Robbins	Nov 09, Thu, 18:49:48.436

Transmission Fault Location

Broken insulator

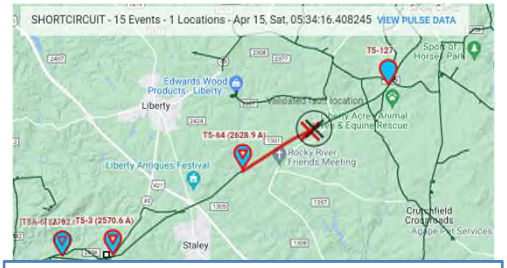
Single reclose and hold

Grid Guardian located within 1 pole span

Immediate action avoided second outage

Locate. React. Repair

Transmission Fault Location



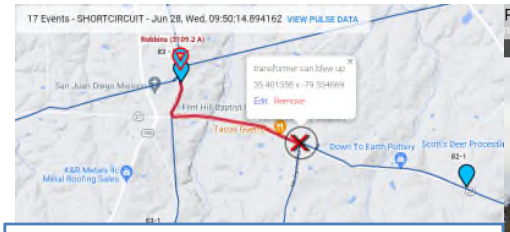
Broken Crossarm

Relay and impedance data indicated location
Off by several miles
3 hours patrolling with no success

Grid Guardian located within 1 pole span

Locate. React. Repair

Case Study

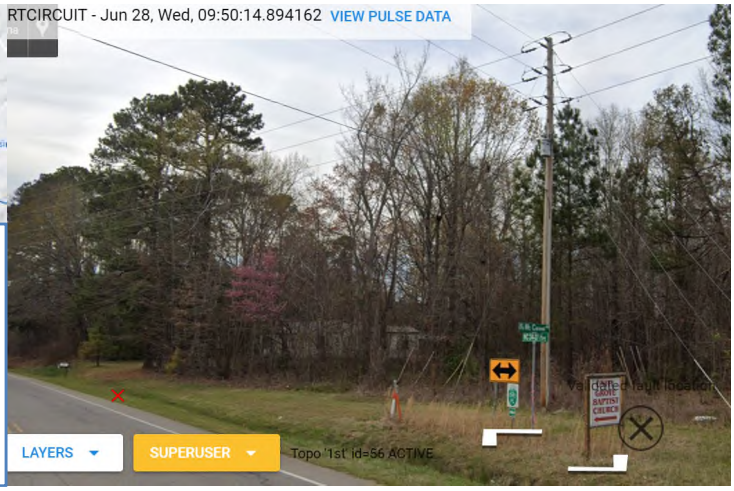


Distribution Fault

Transformer failed

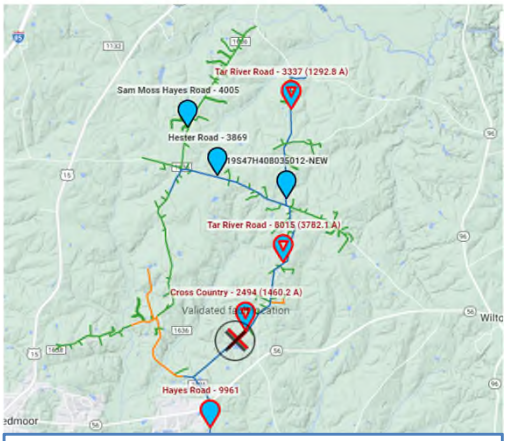
Red X is indicated fault location

Black X is customer validated location



Transformer example

Distribution Fault Location

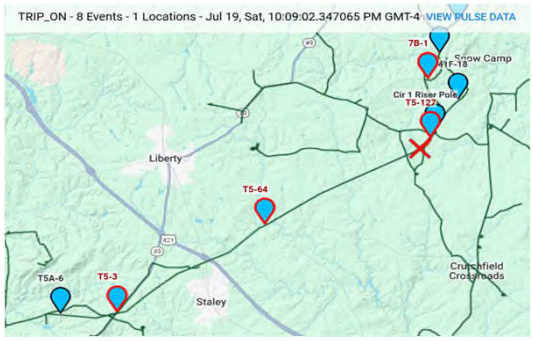


Distribution Fault

Tree on line
One recloser operation held
Tree burning

Tree on line

Fault Location



Tree on Line

- Green tree had bottom phase pinned down
- Fault located within a span
- Saved hours of line patrol

Intermittent Faults

Intermittent Fault

- **End customers complained about blinking lights**
- **Map indicated multiple events occuring in the proximty of the substation**
- **Intermittent earth faults at an indoor secondary substation circuit-breaker bushings.**

Why is Fault Prediction Important?

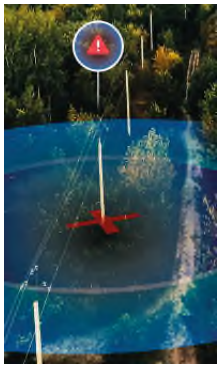
- Move from reactive to proactive maintenance
- Condition based information for electrical system health
- Avoid outages and customer impact
- Reduce O&M spend by working during planned outages

What are the challenges for Fault Prediction?

- Understanding how to manage and integrate data
- Building a work flow to proactively address new types of information

GridGuardian Classification Algorithm

Fault



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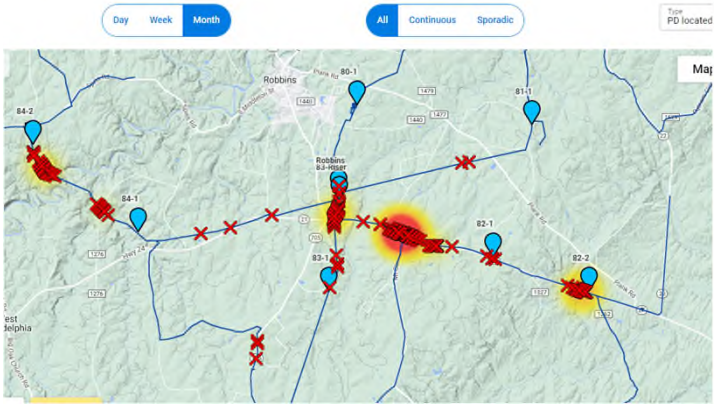
Smart Fault Prediction



Actionable Information - Email or Text Alert

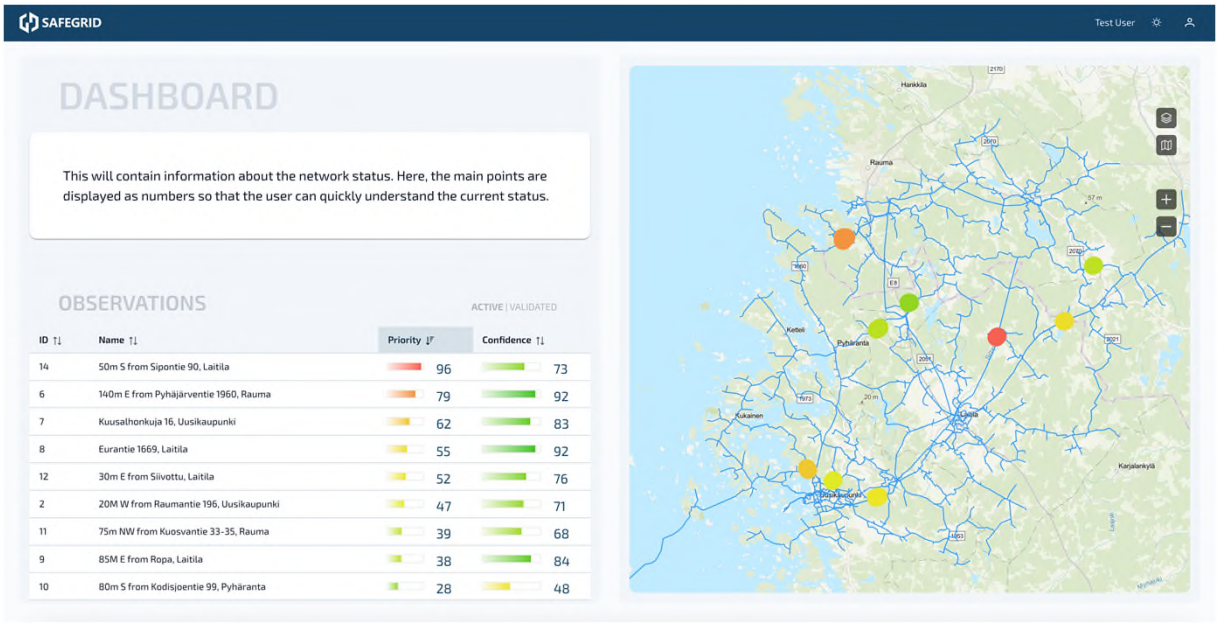
Location Patterns

GridGuardian determines locates all data to provide patterns and hotspots for investigation

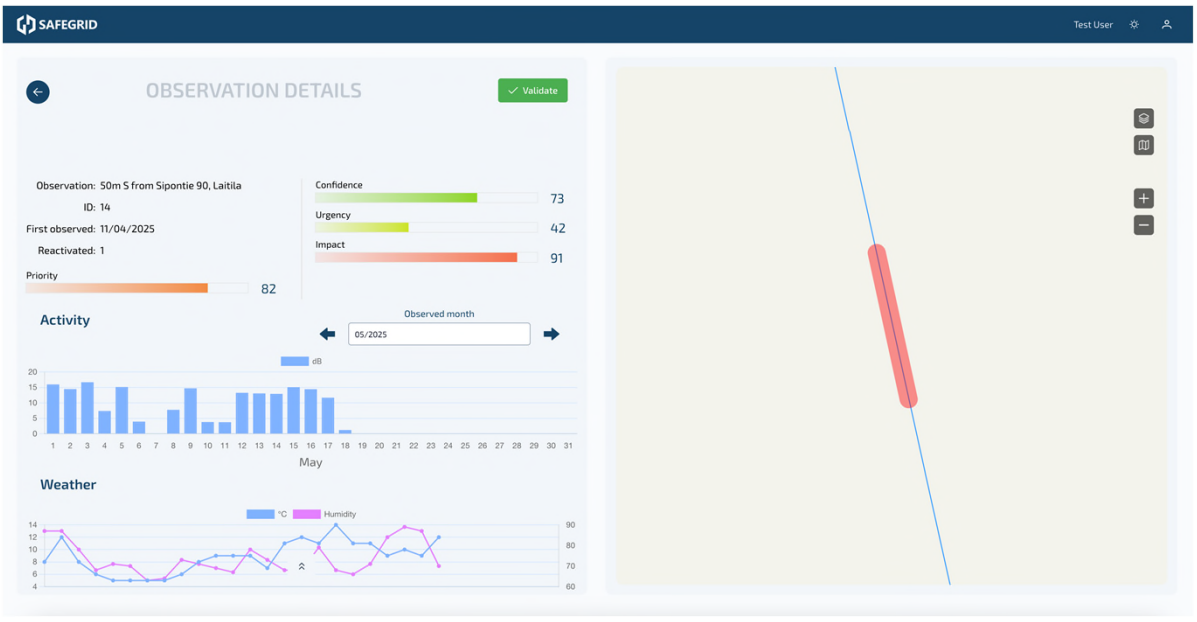
Signatures

Building a library of signatures of fast transient waveshapes that could indicate equipment failures

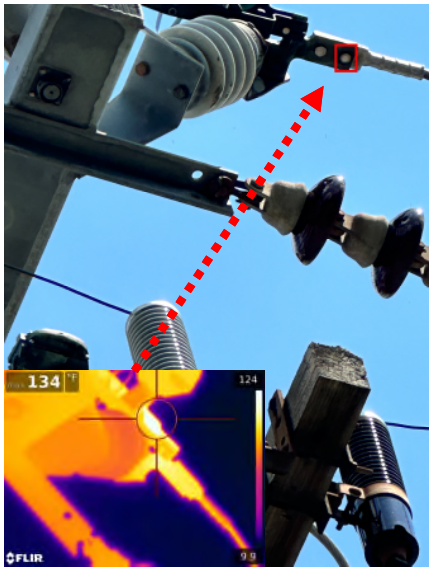
Smart Fault Prediction 2.0



Smart Fault Prediction 2.0



Distribution Fault Prediction



Hot Connector – Pole top switch

Hotspot indicating consistent and persistent concern at location
Infrared camera indicated hot lug connection

Overhead Switches

Use case: failing asset prior to protection action

Beyond accurate fault locating, Safegrid's IGS helps predicting and preventing faults to improve grid reliability. By continuous monitoring, a damaged insulator brinding was identified and replaced within a week, avoiding an outage and saving significant costs.

With Safegrid's solution the DSO achieved:

- **Fault prevented in advance**
- **10 000 € cost savings**

"Safegrid has helped us to locate and prevent component failures we haven't been effectively able to prevent. This has enabled considerable cost savings due its predictive maintenance capabilities"

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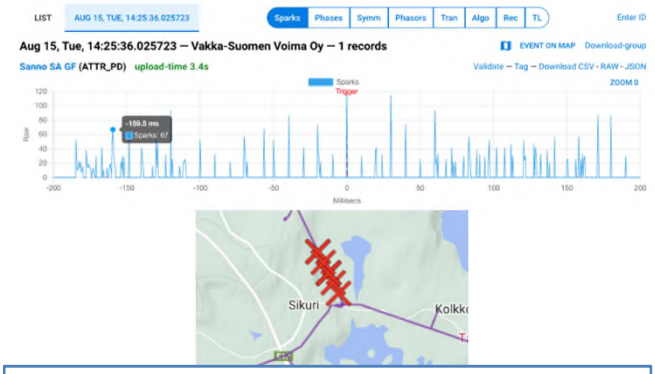
Distribution Fault Prediction

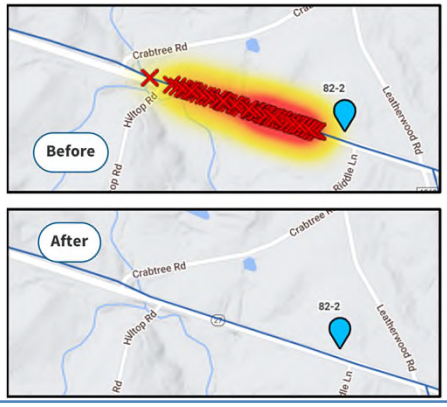


Insulator Failing – Current Leakage

Cracked insulator tracking current
PD sensing identified area and 2 insulators replaced

Insulators

Distribution Fault Prediction

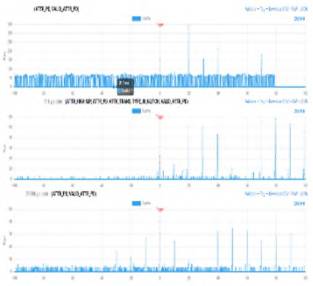


Failing Lightning Arrestor

Arrestor causing PD / leaking current signals

Lightning Arrestor

Distribution Fault Prediction



Failing Transformer - Arcing

PD indicated failing transformer
Oil levels low and corrected to avoid failure

Transformers

Wildfire Considerations

High Impedance Earth Faults

- Vegetation encroachment on live conductors
- Line down and still energize

Protection Scenarios

- Supporting fast trip and patrol requirements

Predictive Data Integration

- Electrical conditions and anomaly data for high-risk areas

Data Driven, Actionable Information

Condition Based - Prediction

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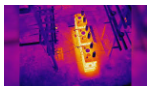
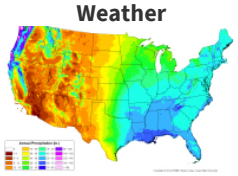
Inspection / Historic

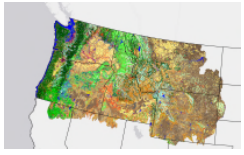


Weather



Fire Risk

Vegetation

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