An aerial photograph of a high-voltage power line tower in a tropical forest. The sun is setting in the background, creating a warm, golden glow. The tower is a complex lattice structure with multiple insulators and conductors. The surrounding landscape is lush and green, with a winding road visible in the distance.

Viking's Broken Conductor Protection Technology ("BCPT")

*Reliable Open Conductor Detection
Using **Existing Relay Infrastructure**
Without Communications*

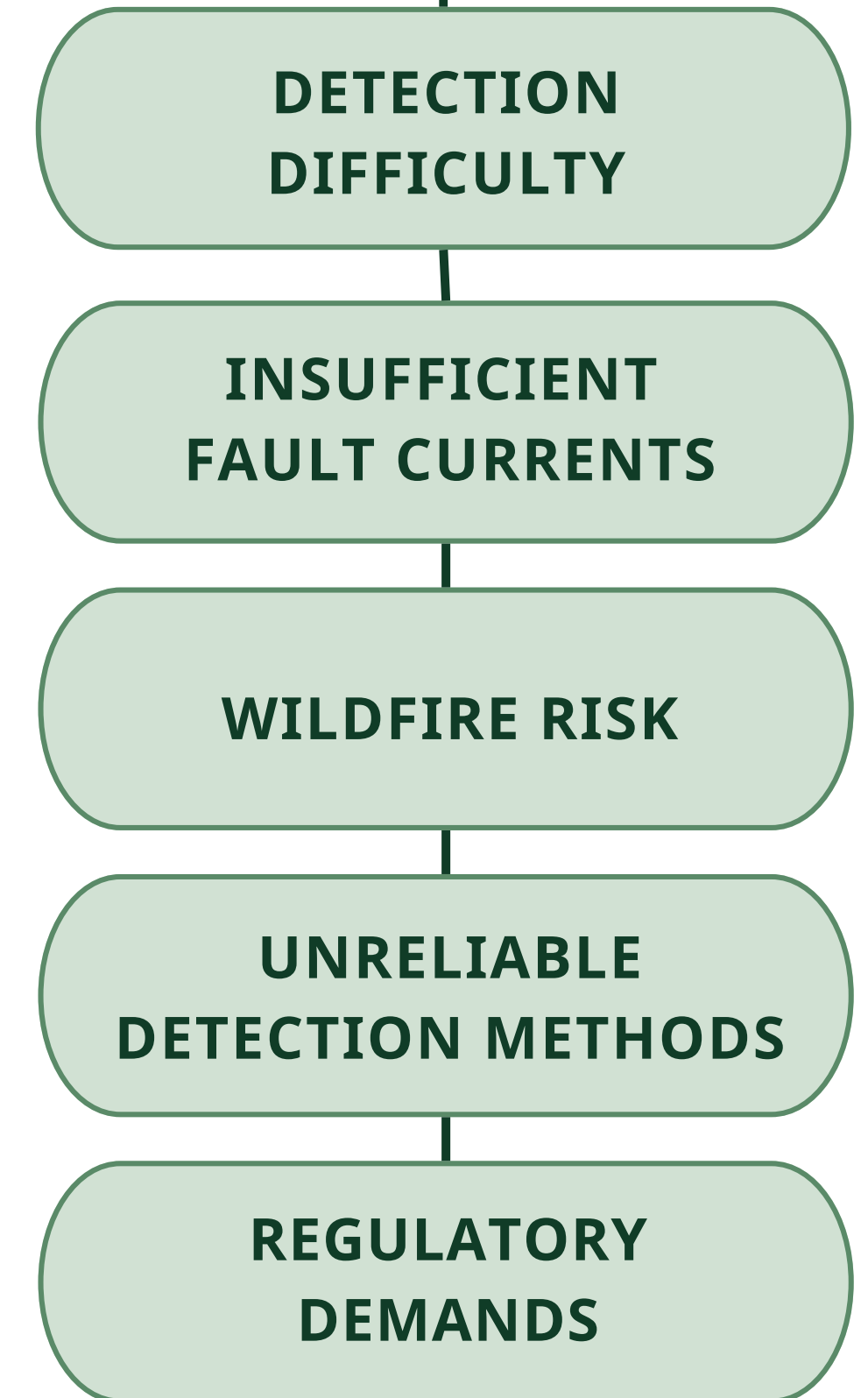
Viking Protection Systems, LLC

THE CHALLENGE

BROKEN CONDUCTOR PROTECTION CHALLENGES

Broken conductor events present detection challenges for conventional protection schemes, *particularly under normal operating conditions* where fault current may be limited or absent.

- ➔ **Broken conductor events are difficult to detect** using conventional protection schemes
- ➔ **These events often produce insufficient fault current** for reliable detection
- ➔ **Conductors may remain energized after failure**, creating safety and wildfire risk
- ➔ **Detection may not occur** under normal system loading conditions
- ➔ **Increasing regulatory and operational focus** on detection and mitigation



PROTECTION GAP

GAP IN EXISTING PROTECTION SCHEMES

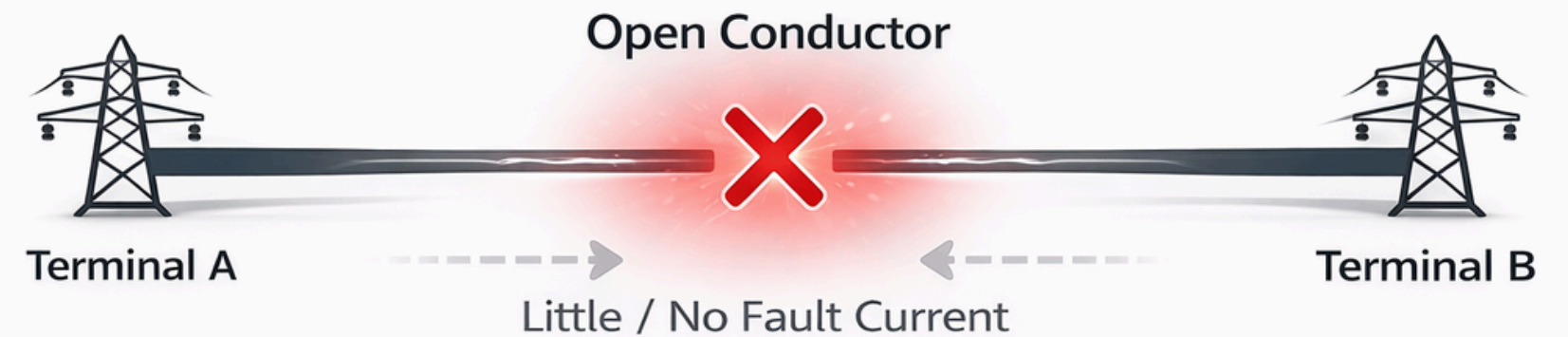
Open conductor detection is *not inherently addressed by conventional protection schemes*, particularly in cases where fault current is limited or not present under normal operating conditions.

Limitations:

- ✗ Detection depends on sufficient fault current
- ✗ May not operate under normal loading conditions
- ✗ Existing elements not specifically designed for open conductor detection
- ✗ Performance varies with system configuration and loading

CONVENTIONAL TECHNOLOGY

✗ MAY NOT DETECT OPEN CONDUCTOR



Result: Open Conductor may go undetected, especially during no-fault conditions

✗ NOT DETECTED / UNPROTECTED

VIKING'S BCPT (PATENTED)

DETECTION CONCEPT

Viking's BCPT leverages the fundamental electrical behavior of transmission lines under open conductor conditions, using the resulting current-voltage relationships and capacitive effects to identify distinct, measurable signatures for detection.

Physics Behind Detection:

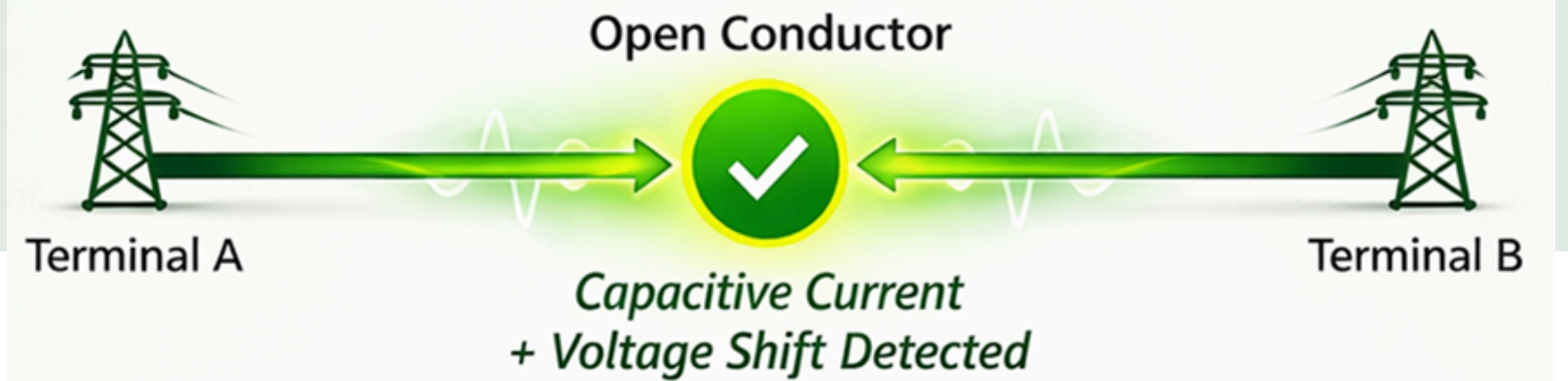
- Leverages fundamental transmission line physics
- Line susceptance influences SIR (surge impedance loading)
- Open conductor → end capacitance dominates
- Leading ($\approx 90^\circ$) capacitive current flows into both line ends

Detectable Conditions:

- Differential current across the open conductor
- Very low current magnitude in the broken phase
- Reverse-directional overcurrent response
- Phase current imbalance

VIKING'S BCPT TECHNOLOGY

✓ DETECTS OPEN CONDUCTOR



📶 MULTI-PARAMETER DETECTION



Detection Foundation

Leverages fundamental transmission line physics



Capacitive Signature Detection

Identifies π -section line response



Pattern Recognition

Multiple operating condition checks



Adaptive & Secure

Stable – Selective – Low False-Trip Risk



Result: Reliable detection of open conductor under **all loading conditions**

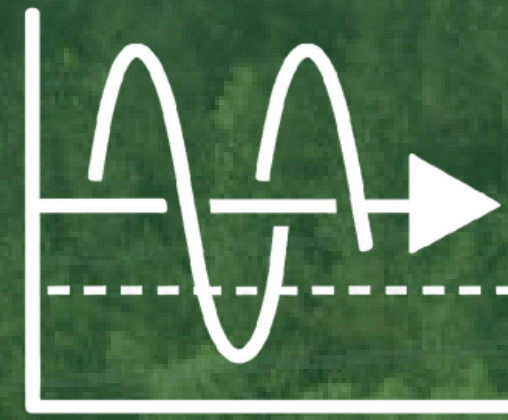
VIKING'S BCPT (PATENTED)

DETECTION METHODOLOGY

Advanced Multi-Parameter Detection

Viking's BCPT applies a multi-parameter detection methodology that analyzes current and voltage behavior to identify broken conductor conditions. The approach leverages fundamental transmission line behavior under open-conductor conditions, where capacitive effects and resulting current characteristics create distinct, detectable signatures.

Viking's BCPT combines several complementary analytical checks to ensure reliable detection while maintaining stable operation during normal system conditions and minimizing the risk of false trips.



**Undercurrent
Magnitude & Rate-
of-Change Analysis**



**Negative Sequence
Current Variation
Monitoring**



**Phase
Imbalance
Detection**



**Voltage-
Based
Validation**



**Multi-Stage
Filtering for
Stability**



**False
Trip
Prevention**

SECURITY ALGORITHMS

& VALIDATION LOGIC

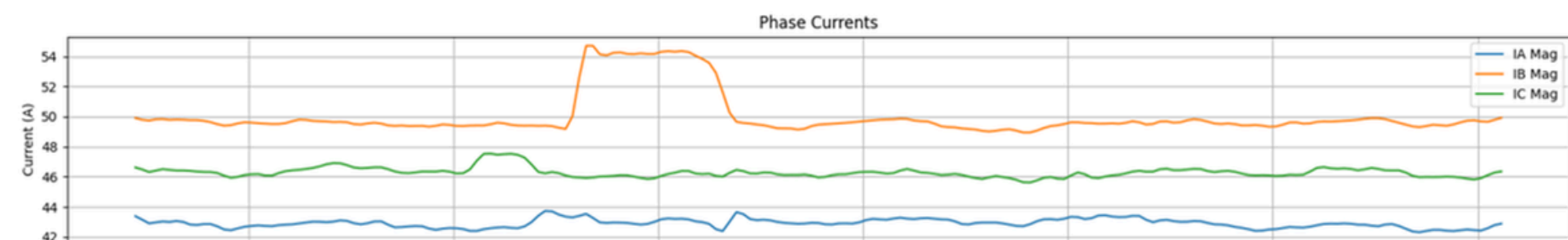
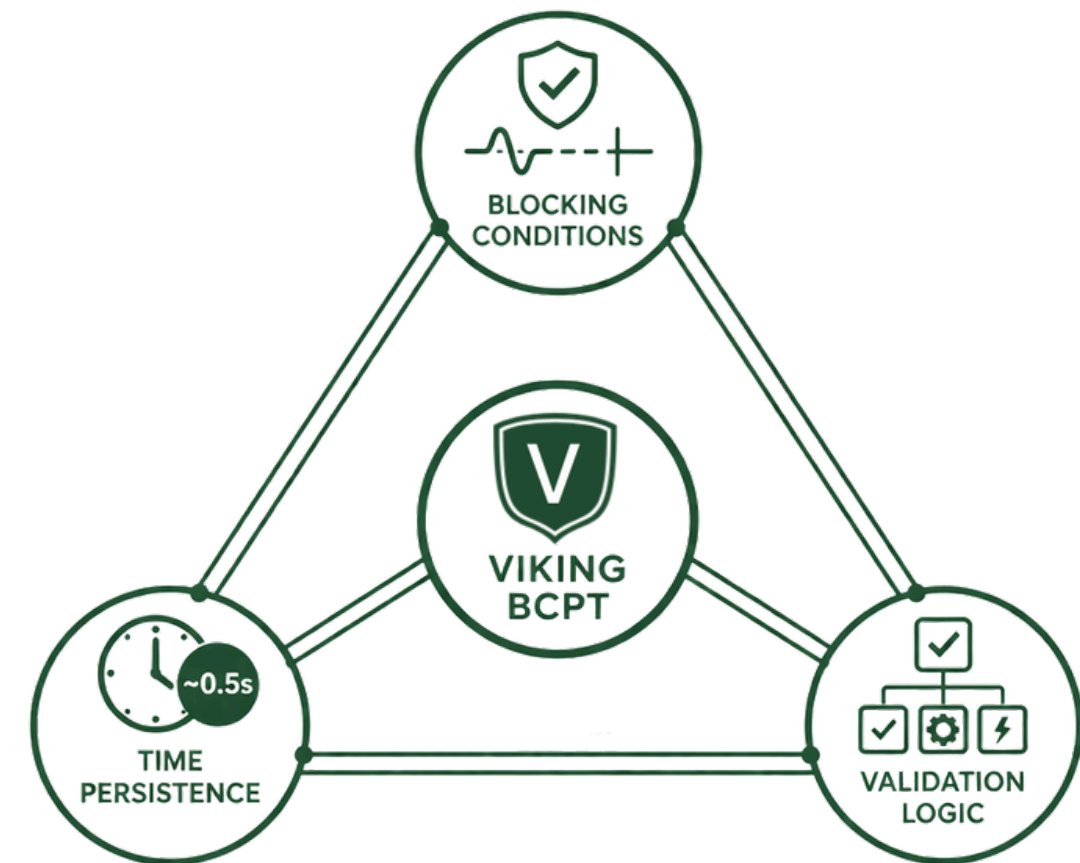
Viking's BCPT incorporates blocking conditions and validation checks to ensure secure operation and minimize false trips under non-fault conditions.

Blocking Conditions

- Applies voltage-based blocking conditions
- Applies minimum current thresholds
- Incorporates fault current blocking logic

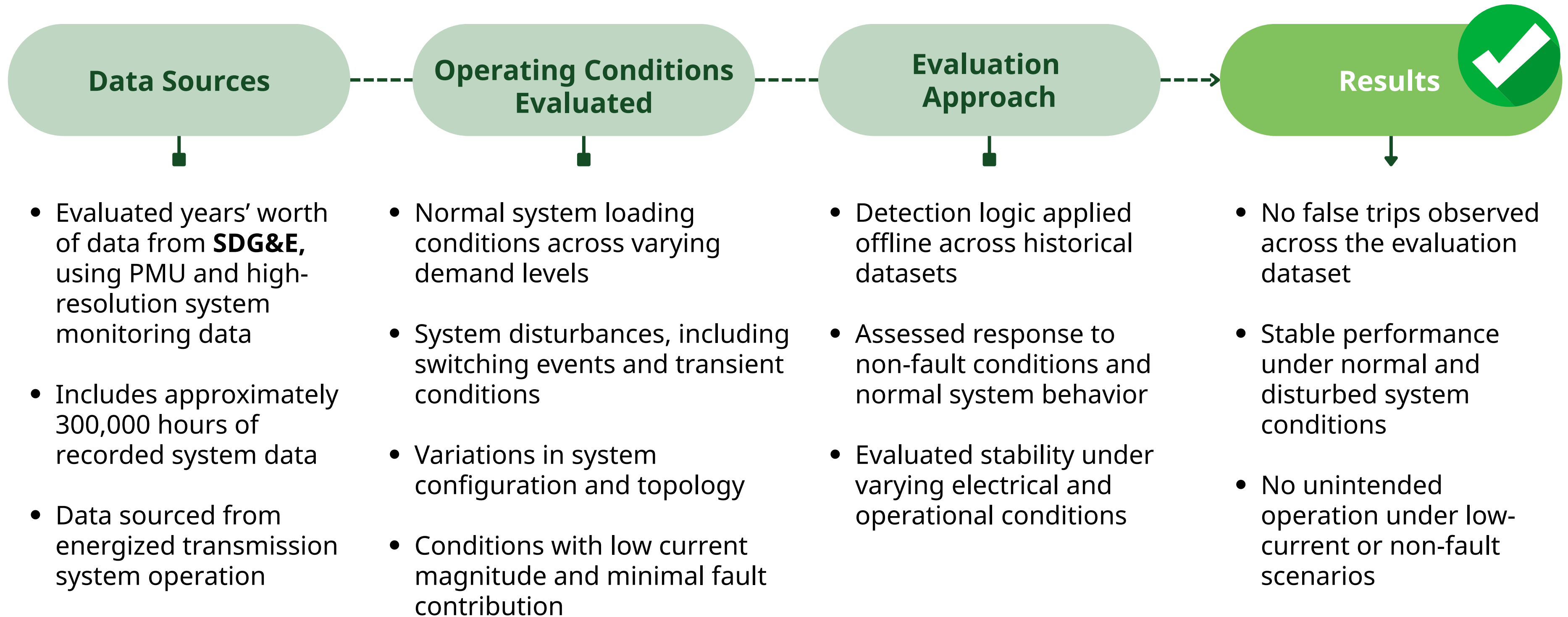
Validation Logic

- Evaluates phase-specific current changes
- Requires conditions to remain present for approximately 0.5 seconds prior to operation
- Uses multi-stage validation to prevent unintended operation



VALIDATION | SYSTEM DATA

Viking's BCPT protection logic was evaluated through **SDG&E-specific modeling and coverage analyses**, assessing performance across a wide range of operating conditions and system states.



— VALIDATION | LIVE SYSTEM TESTING

PERFORMED BY: **FirstEnergy**

Viking's BCPT was validated through live testing on an energized 138 kV transmission line (~63 miles), with open conductor conditions simulated under real system loading and operating conditions.

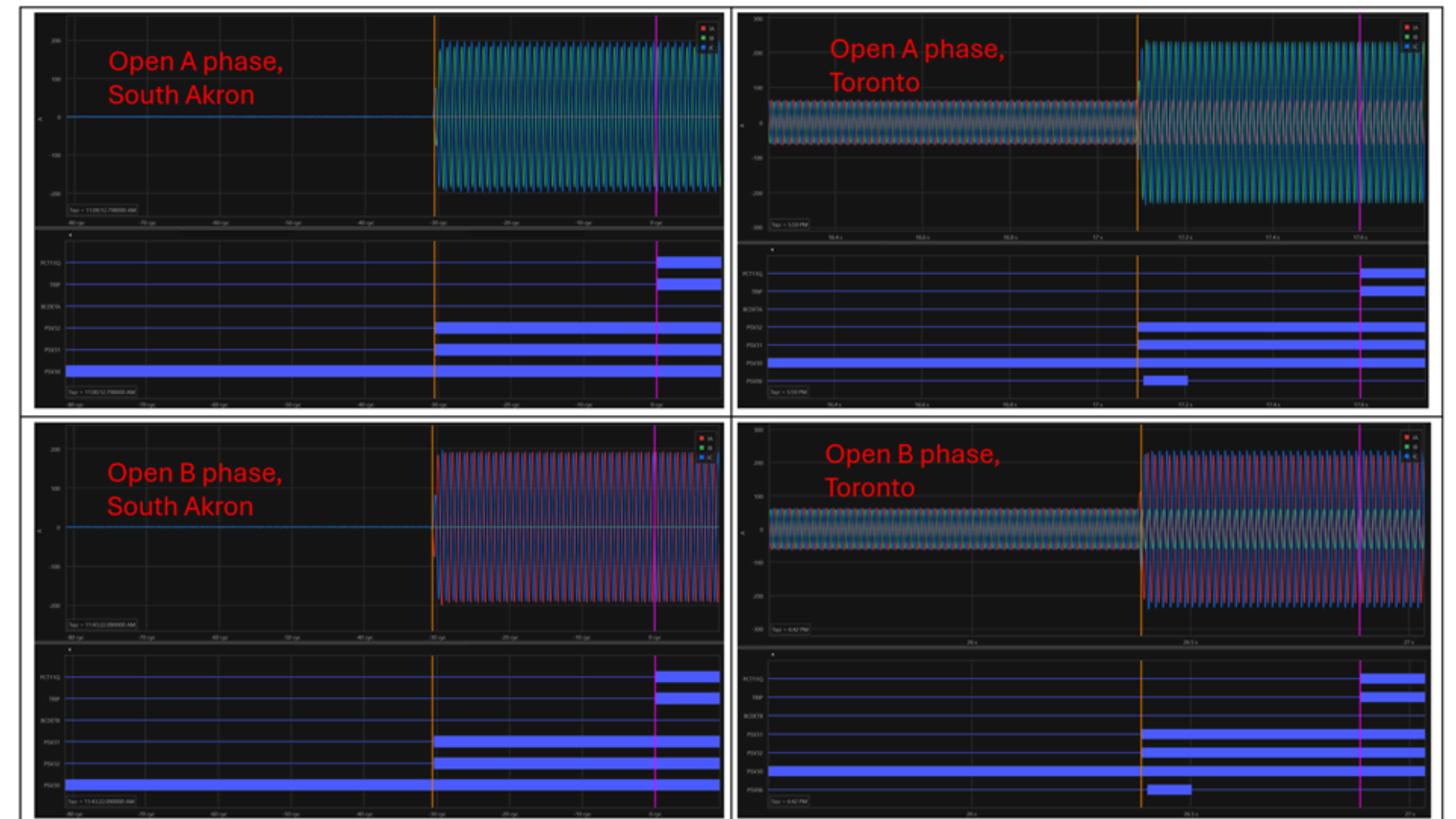
Results: Line 1 (Protected Line)

- Viking's BCPT successfully detected all open A-phase & B-phase events
- Detection occurred at both line terminals
- Operated correctly under real system loading conditions

Results: Line 2 (Adjacent Line)

- Viking's BCPT did NOT operate during external open conductor events, as designed
- Zero false trips recorded
- Maintained stability during switching conditions

SEL native broken conductor elements did NOT detect events



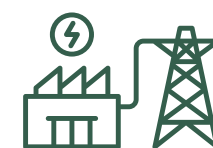
Detection confirmed at both terminals



Validated via sequence-of-events and oscillography



Demonstrated performance under real system loading



138 kV energized transmission line (~63 miles)



Sub-second trip logic assertion



No false trip on adjacent line

VALIDATION & TESTING CONCLUSIONS

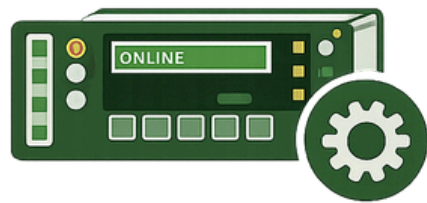
Testing results demonstrate *dependable protection* performance with secure operation across real-world transmission conditions.

- Detects open conductors across all voltage levels and topologies (two-terminal and multi-terminal)
- Proven on short radial lines (down to ~60 kV / ~5 miles) — no external communications required
- Leverages highly sensitive undercurrent detection (~0.01 A) using existing relay platforms (SEL, Basler, Eaton Form 7)
- Uses instantaneous metering values — no hardware upgrades required
- Secure operation:
 - No operation for external faults
 - No operation above ~0.2% load conditions
 - No operation under balanced load
 - No misoperation from load unbalance on untransposed lines
- Enhanced protection capability
- Minimum-effort deployment via logic updates on existing microprocessor relays



RELAY-INTEGRATION & OPERATION

Integration Model

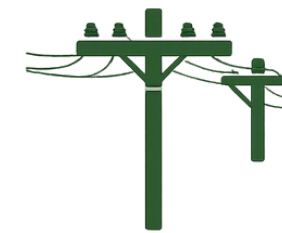


- ✓ Implemented within existing microprocessor-based relays (incl. SEL 400, 700 & 900 series)
- ✓ Uses instantaneous metering values and relay logic
- ✓ Requires no external communications
- ✓ Requires no additional hardware or field devices
- ✓ Applicable to platforms including SEL, Basler, and Eaton controllers
- ✓ Can be deployed at both line terminals for coordination detection

Operational Workflow



Substation relay continuously monitors line conditions



BCPT algorithm evaluates current and sequence parameters



Detection occurs during open-conductor conditions



Trip logic asserted by the relay



Protection action initiated per utility configuration

DEVELOPMENT & VALIDATION HISTORY

PROGRESSION
FROM CONCEPT



MODELING



BRANCH
TESTING



SIMULATION



INDUSTRY
ENGAGEMENT



FIELD
TESTING

PHASE 1

Initial Development &
Proof of Concept



- Technology developed and initial modeling completed
- Simulated open conductor on PG&E 500 kV system (WECC power flows)
- Modeled Caribou-Table Mountain 115 kV line (Paradise Fire scenario)

1

PHASE 2

Patent Development &
Technical Validation



- Core detection methodology refined
- Patent filings and technical due diligence completed

2

PHASE 3

RTDS Simulation
Testing



- RTDS testing conducted at Nayak Labs
- Performance validated under simulated conditions

3

PHASE 4

Industry Engagement
& Platform Validation

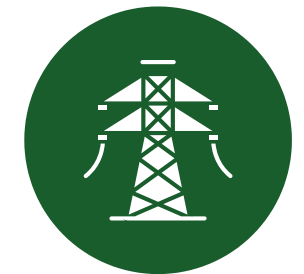


- Technical discussions with SEL R&D
- Validated at Eaton Recloser Test Facility (Milwaukee)

4

DEPLOYMENT

Live System
Validation

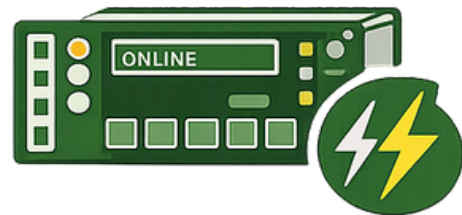


- Deployed in demo mode on RTAC (SDG&E)
- Live transmission testing with FirstEnergy

5

PARTNERING WITH VIKING

APPROACH



Viking and its affiliated entities develop advanced protection technologies designed to enhance grid safety, reliability, and operational performance across transmission and distribution systems.

Viking's patented BCPT solutions are purpose-built for **seamless integration into OEM relay** platforms and utility protection environments.

EXPERIENCE



Core technology developed by **Bob Stuart**, a recognized protection systems expert with **50+ years of experience** across generation, transmission, and distribution, including 35 years with PG&E leading system protection, operations engineering, and reliability initiatives.

Proven track record in advanced protection design, remedial action schemes, and grid reliability innovation.

CONTACT



For partnership discussions or technical engagement:

James A. Doris, President
jdoris@vikingenergygroup.com
(281) 404-4387

Bob Stuart, Inventor
bstuart@bridgeviewllc.com
(925) 596-5427

Armond Greenberg, Mechanical Engineer
armondg@bridgeviewllc.com
(707) 628-0973

Enabling next-generation protection capabilities through relay-integrated innovation!