

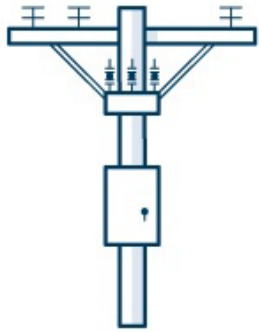


Practical Experience With High-Impedance Fault Detection in Distribution Systems – Continued

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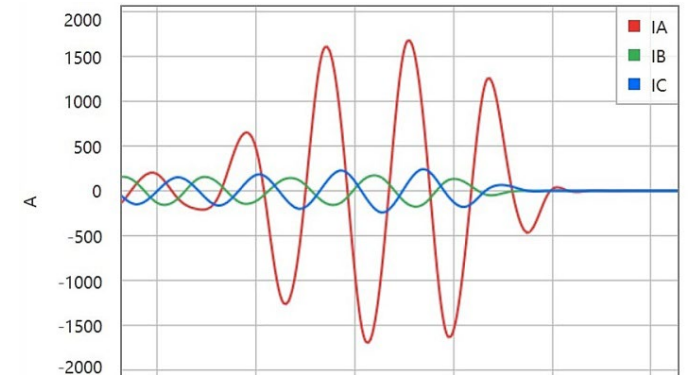
Overview



Expected operation



Detection experience
summary

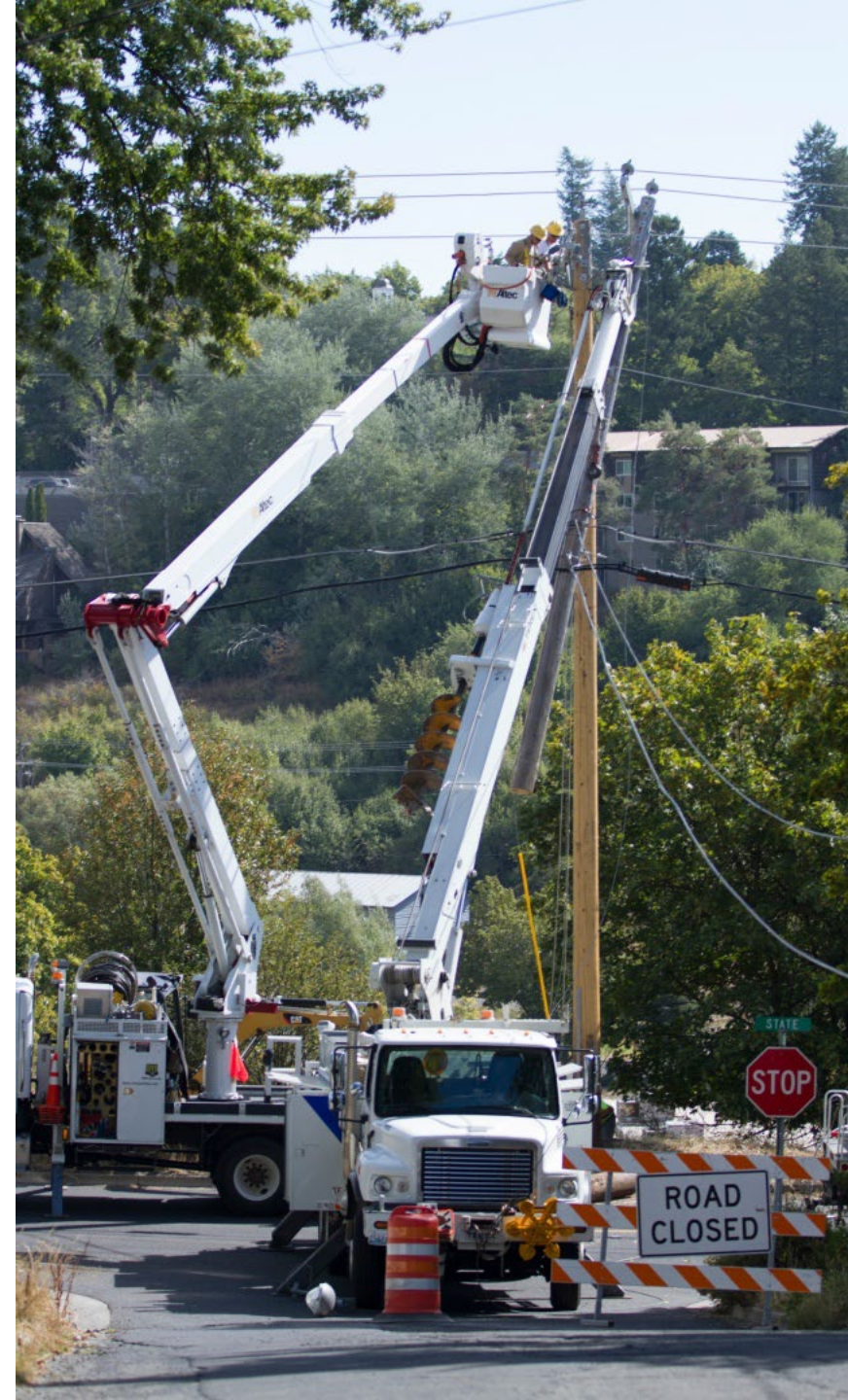


HIF event analysis
and lessons learned

Expected operation

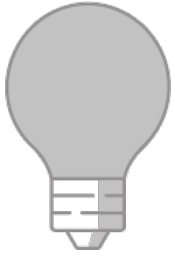
Summary

- HIF algorithm in feeder relays and recloser controllers
- Secure alarming logic to SCADA built using phase independent outputs
- Manual operation performed by system operators
- Automatic isolation logic

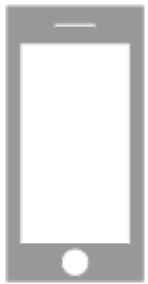


Expected operation

Indications to perform manual operations



Sudden load reduction, including total loss of load



Calls from end users about sparking wires or poor voltage



Loss of voltage on downstream device but voltage present on upstream device

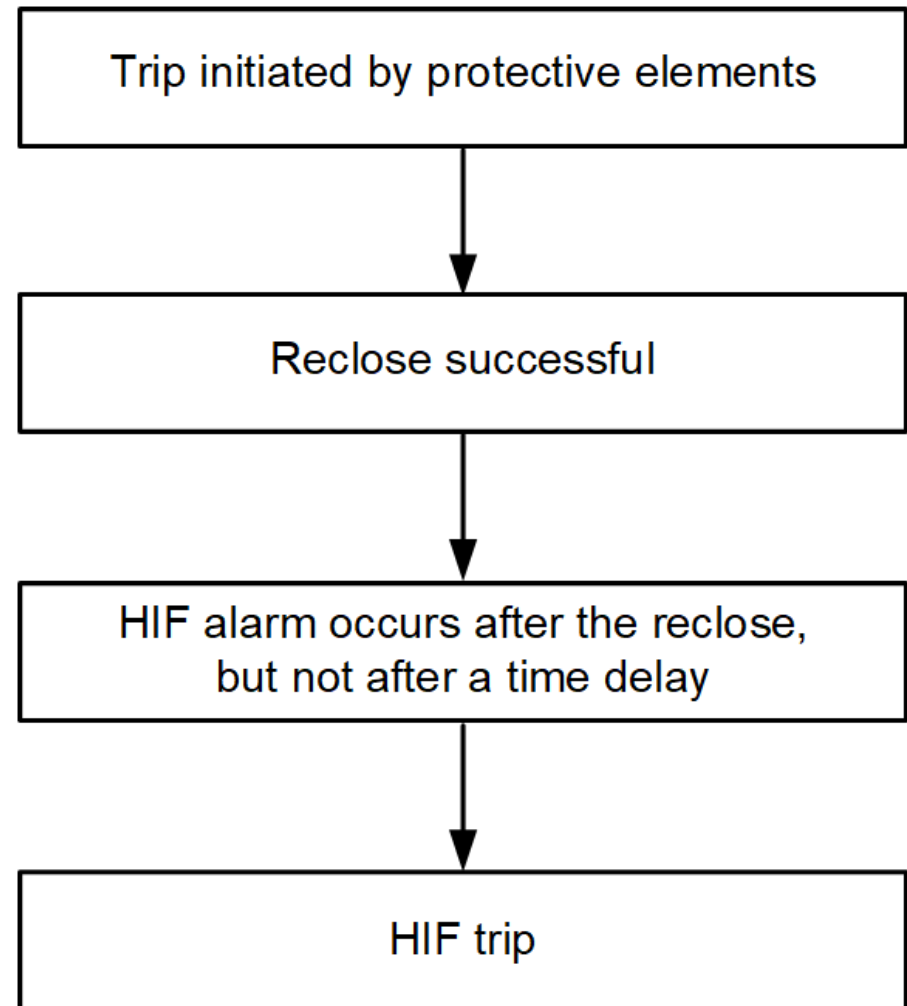


Emergency services call(s)

Expected operation

Automatic isolation

- HIF_TRIP – only occurs if there is an HIF secure alarm(s) 15 minutes after reclosing
- HIF_TRIP_ENABLE_TIMER – starts after first two reclosing shots
- HIF_SUPERVISION_TIMER logic
- Remote enabled by SCADA control



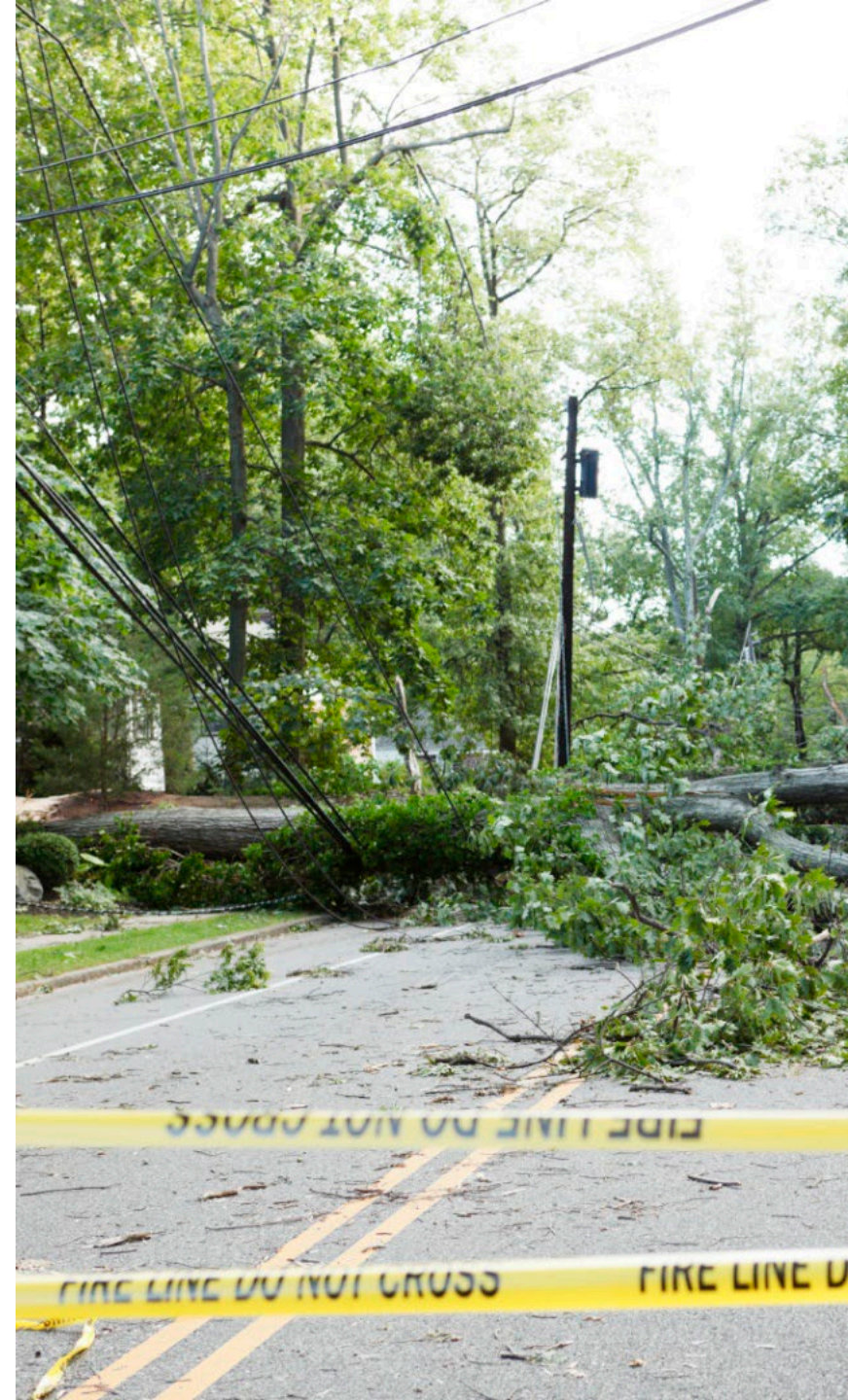
HIF detection experience summary

- Detection rate of 94% over 3 years
 - Two events did not exceed the tuning threshold
- 8 false operations related to
 - Mylar balloons
 - Pending firmware upgrade to improve 3PH_EVE

HIF outcome	Number of events	Percent of total
Successful automatic HIF operations	10	30%
Successful manual HIF operations	21	64%
HIFs that were unable to be detected	2	6%

HIF event analysis and lessons learned

- Car accident resulted in manual isolation
- Tree limb caused HIF trip
- HIF algorithm revealed tree encroachment
- Multiple reclosers detected downed conductor
- HIF algorithm detected failing capacitor bank

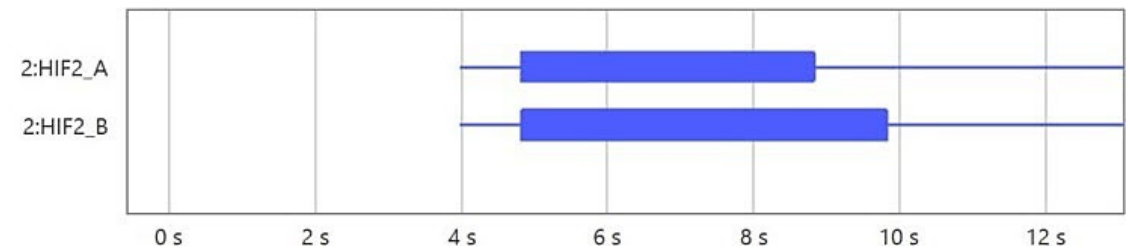
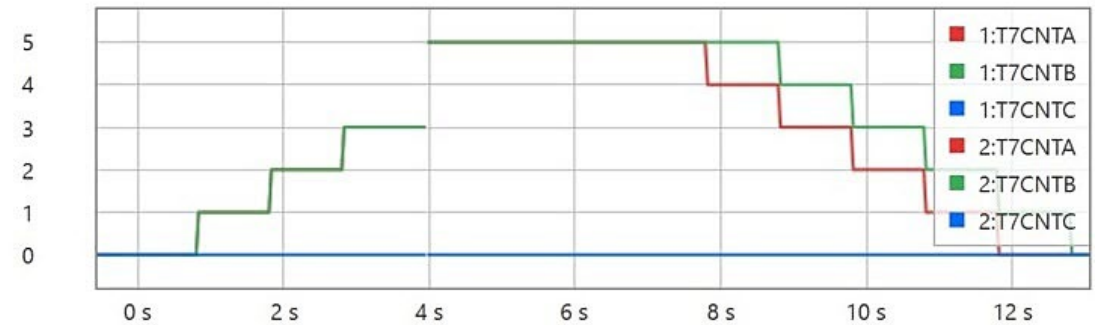
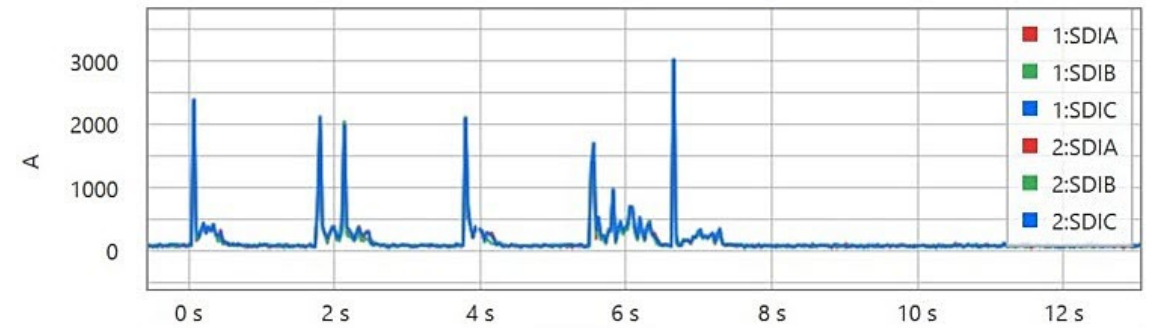
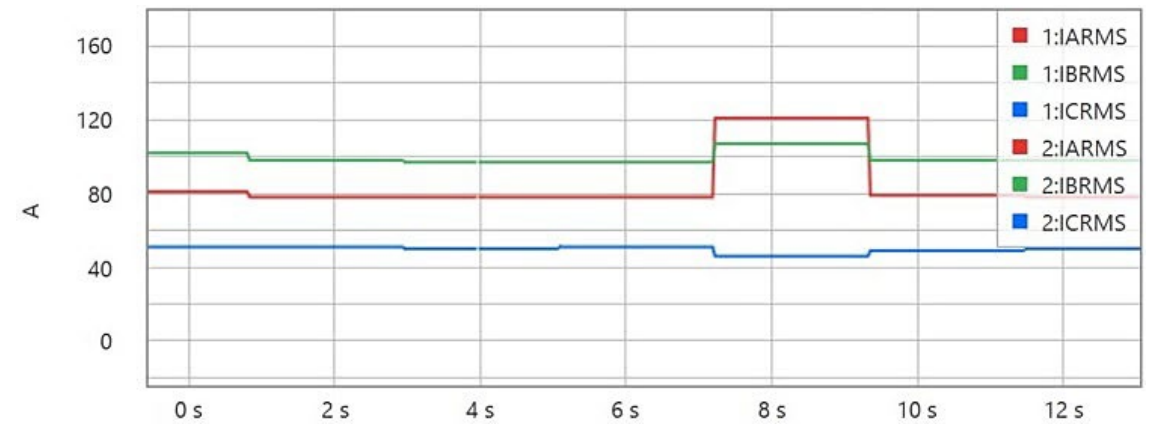


Car accident resulted in manual isolation

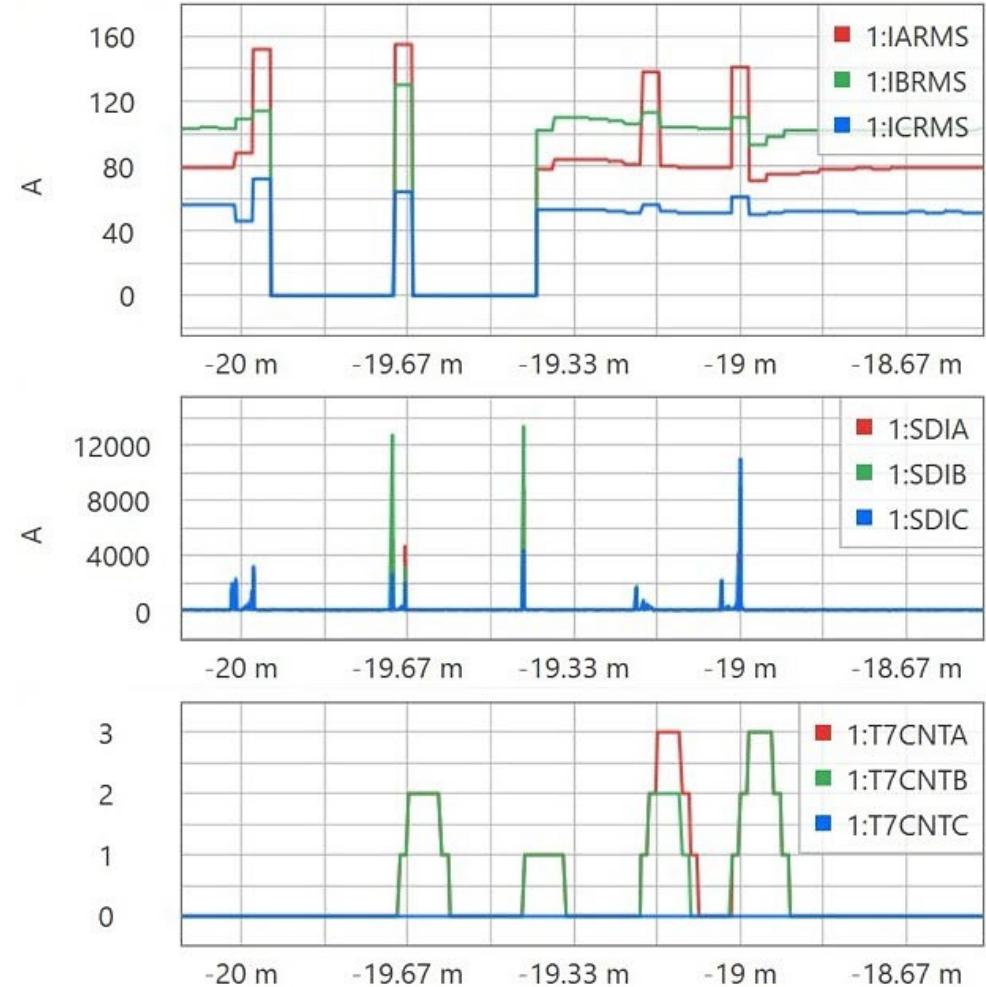
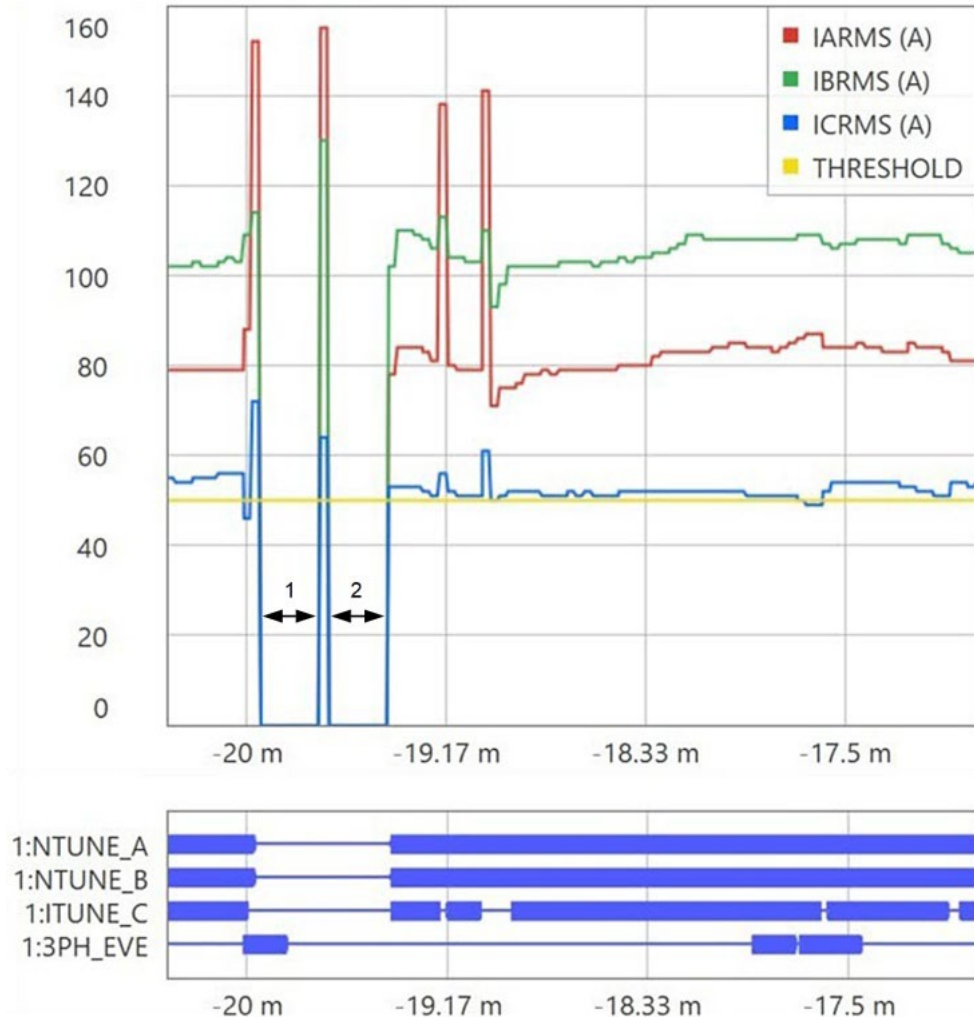
- Event preceded automatic isolation logic
- System operators received HIF alarms
- Recloser controller isolated manually



HIF2 asserts on Phases A and B 5 seconds after SDI activity was detected



Analysis shows downstream reclosing and SDI activity 20 minutes prior



Lessons learned



Event detection would have been delayed waiting on emergency calls



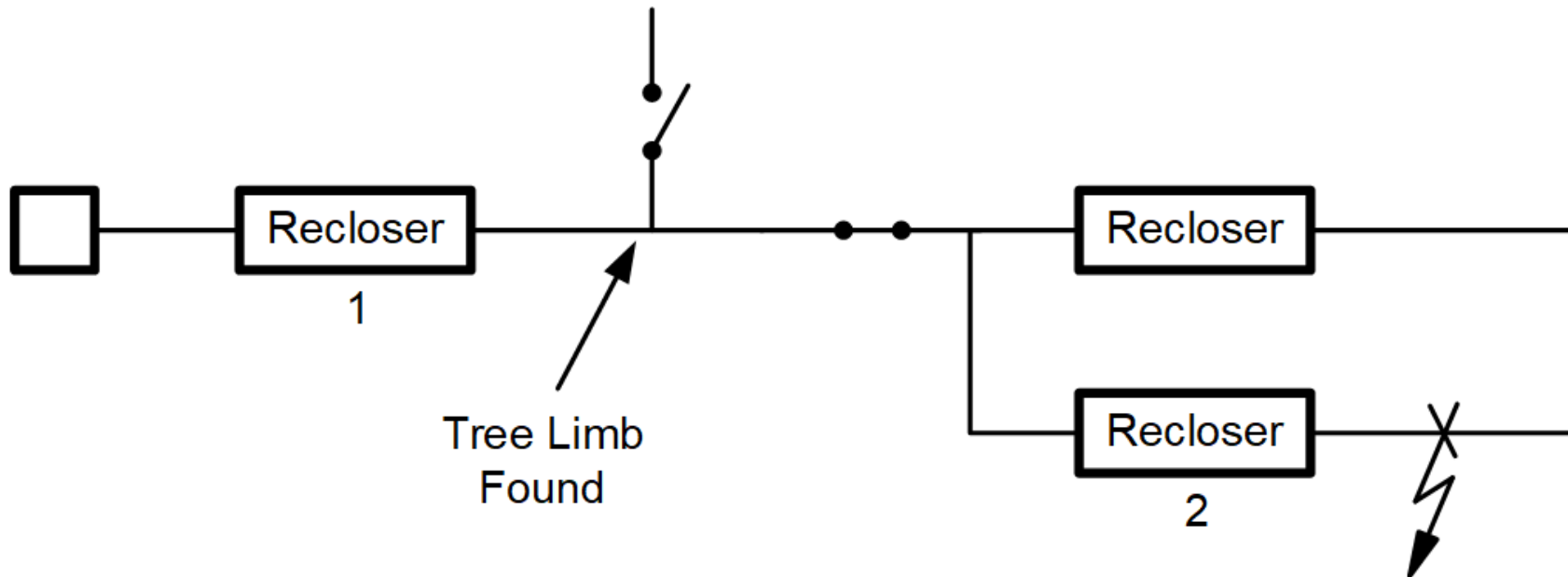
HIFMODE could help improve detection and speed



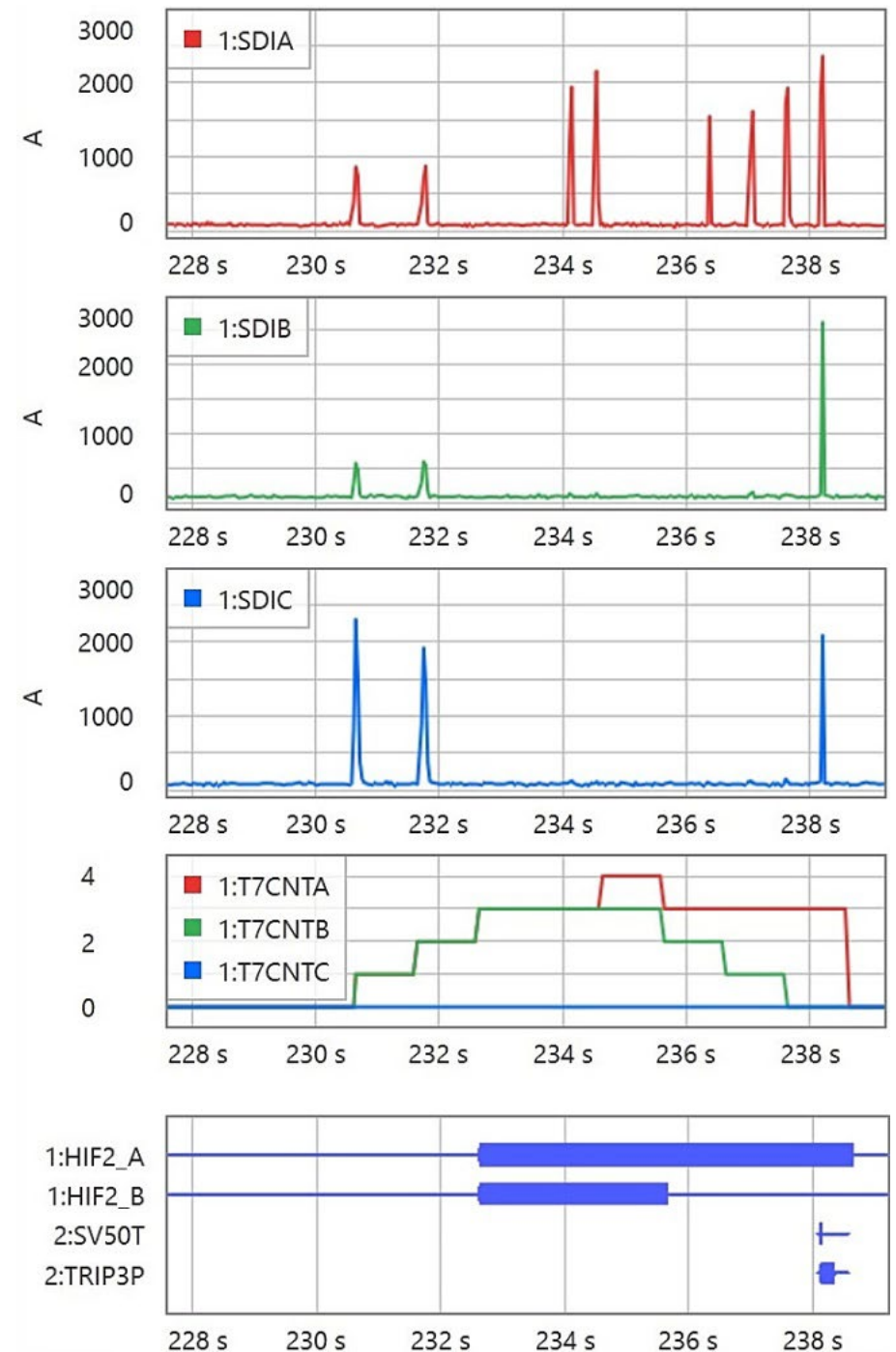
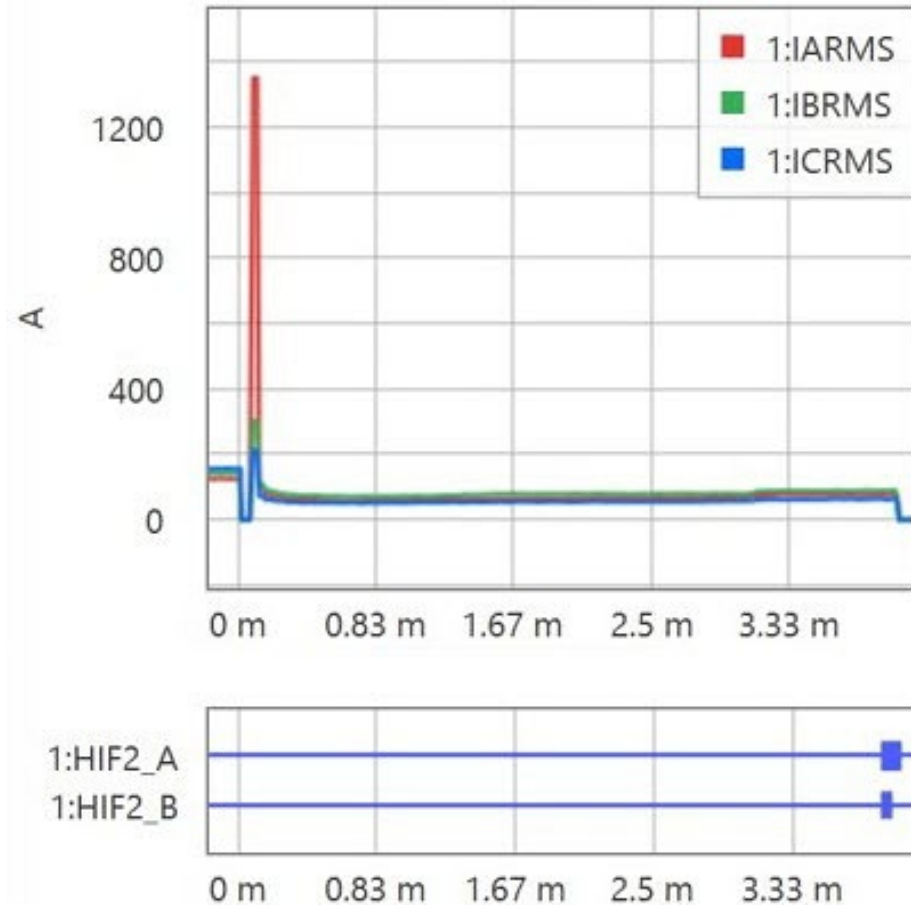
Retrieval of all data could help for future events

Tree limb caused HIF trip

- A downstream fault caused Recloser 2 to operate
- Recloser 1 tripped on the HIF trip logic
- A tree limb was found on a line by a line patrol



Recloser 1 tripped on the HIF logic 3 minutes later



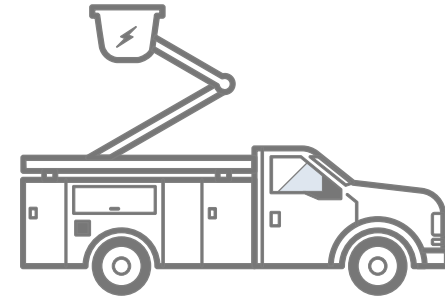
Lessons learned



SDI signature may be arcing from a tree limb (reference for future events)



HIF trip logic is both secure and dependable



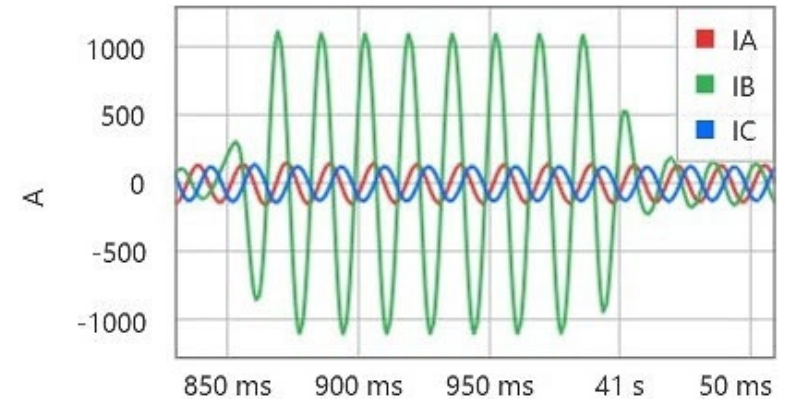
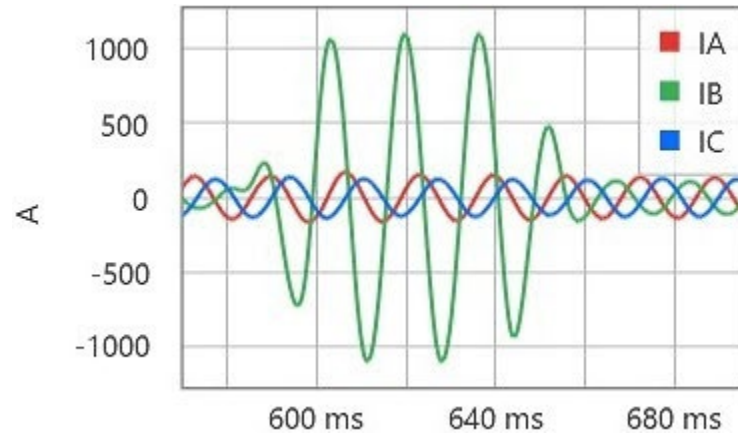
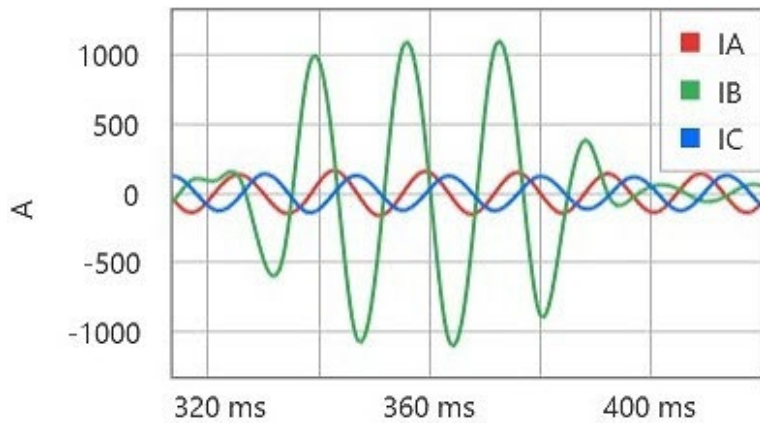
Line crews look for more than just downed conductors after operation

HIF algorithm revealed tree encroachment on a distribution line

- Tree limb repeatedly contacts medium-voltage line
- Relays do not trip on traditional protective elements
- End users complain of flickering lights

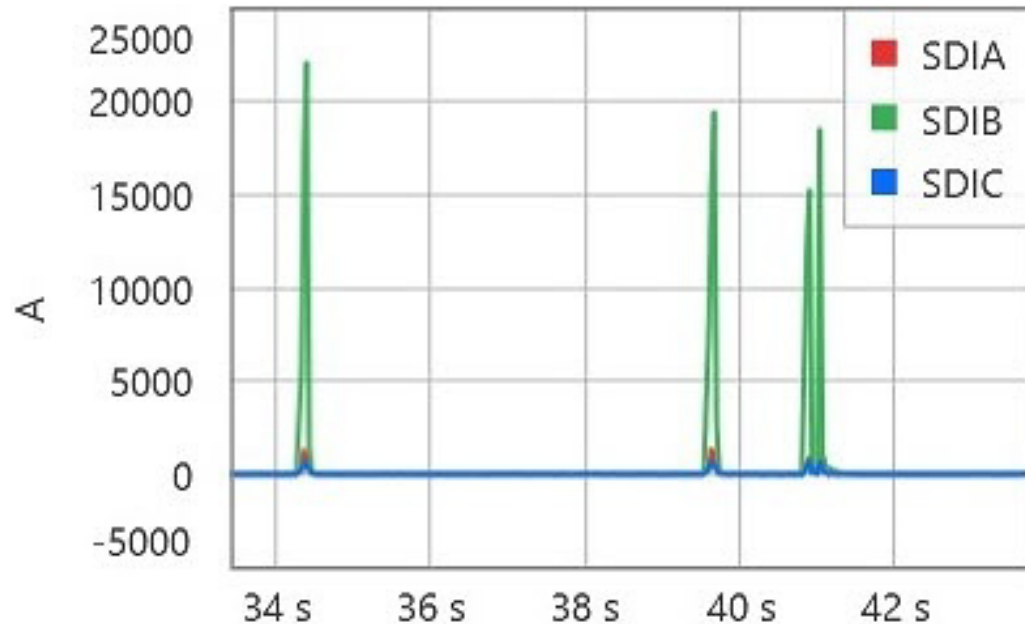
Time	Phase	Magnitude
18:24:34.334	BG	800
18:24:39.610	BG	795
18:24:40.868	BG	808

Oscillography of each BG event

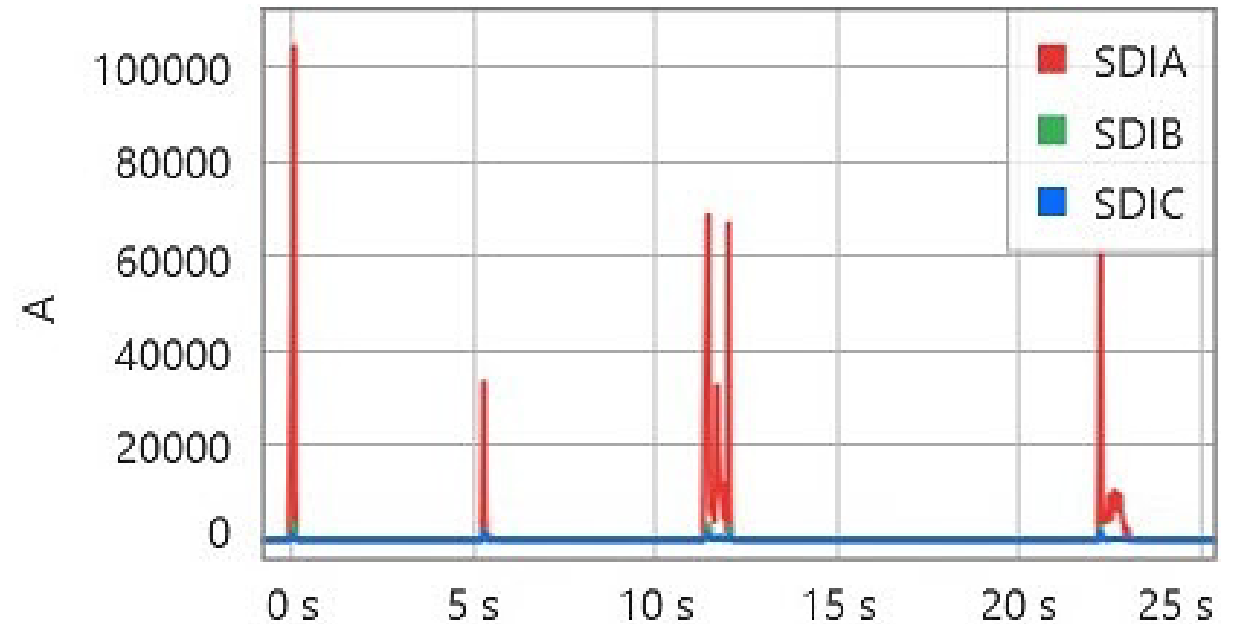


HIF algorithm led investigative patrol to find burn marks on the line from trees

Third arcing event



Event from two years prior



Lessons learned

Intermittent alarming

- This event was two years in the making
- Investigation revealed arcing residue on the line

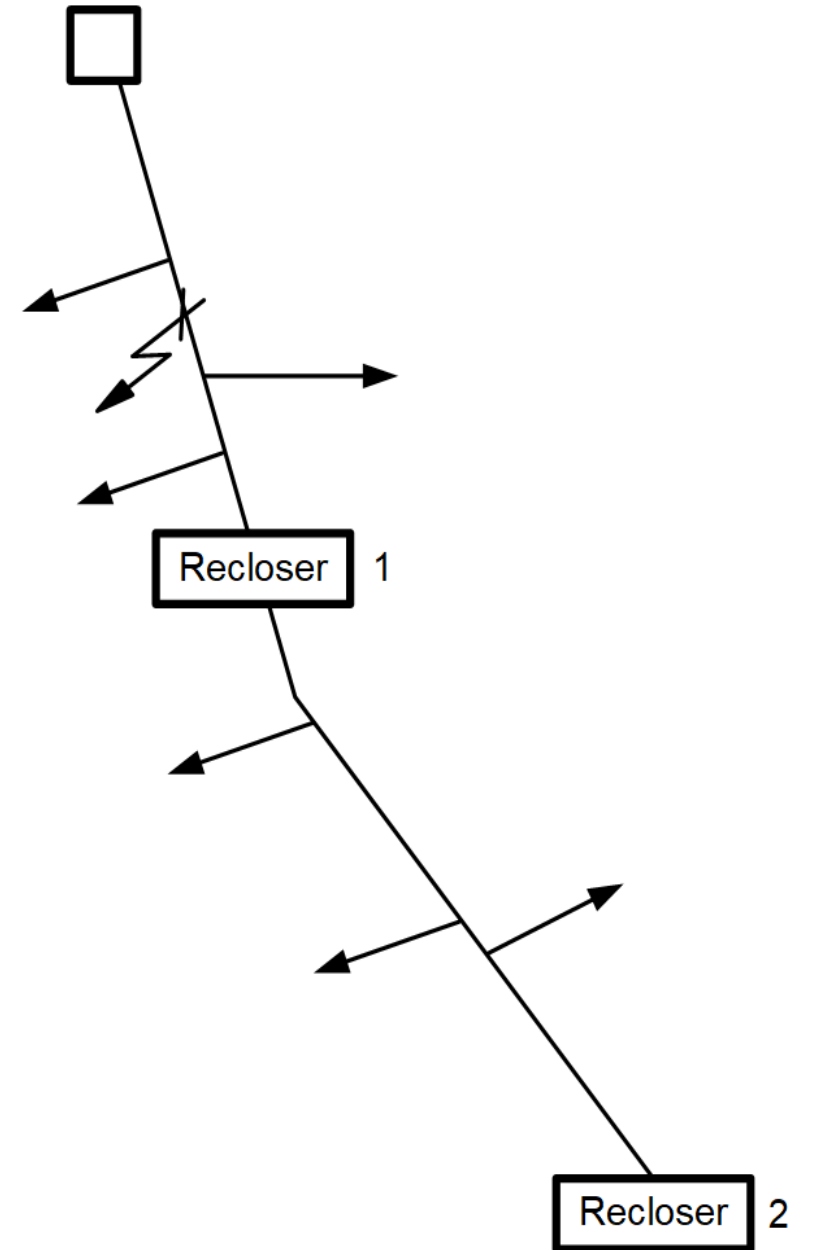
Future innovation

- Detection could lead to proactive tree-trimming strategy based on HIF algorithms

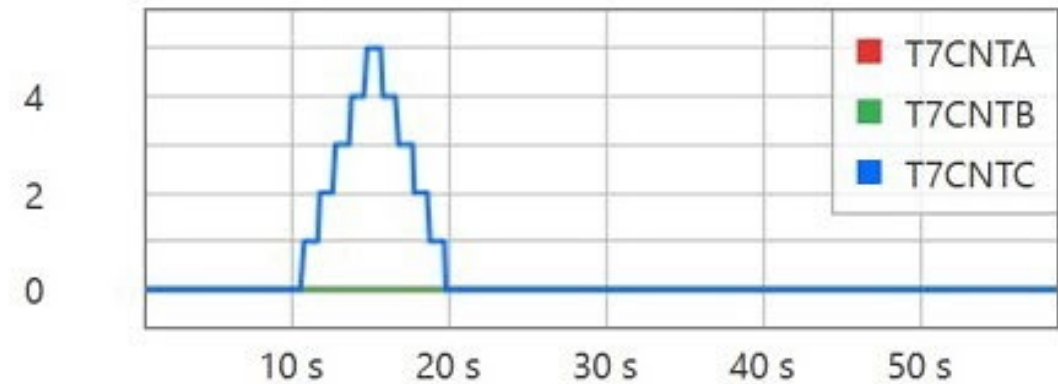
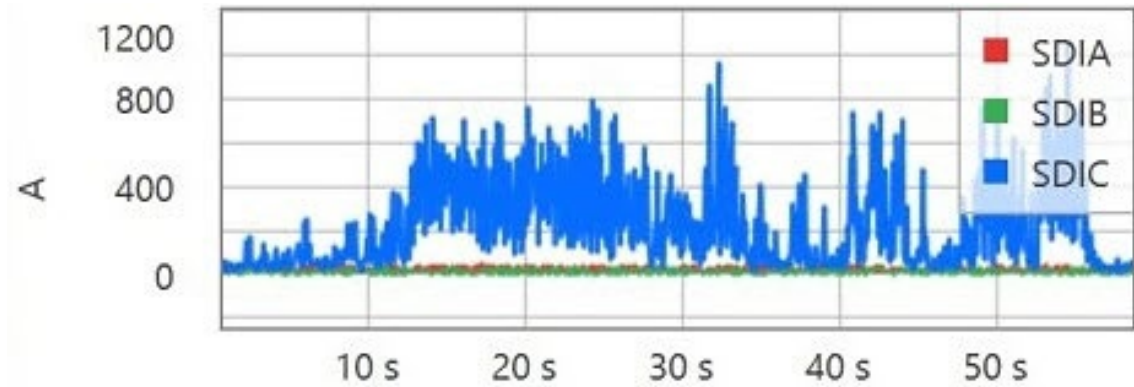
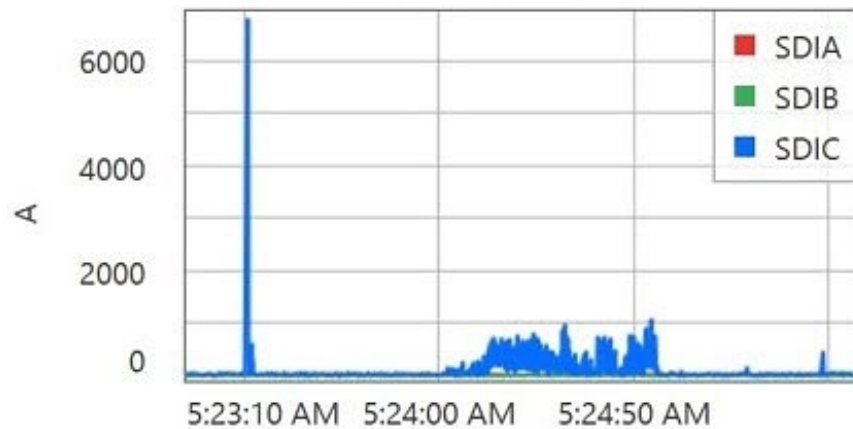
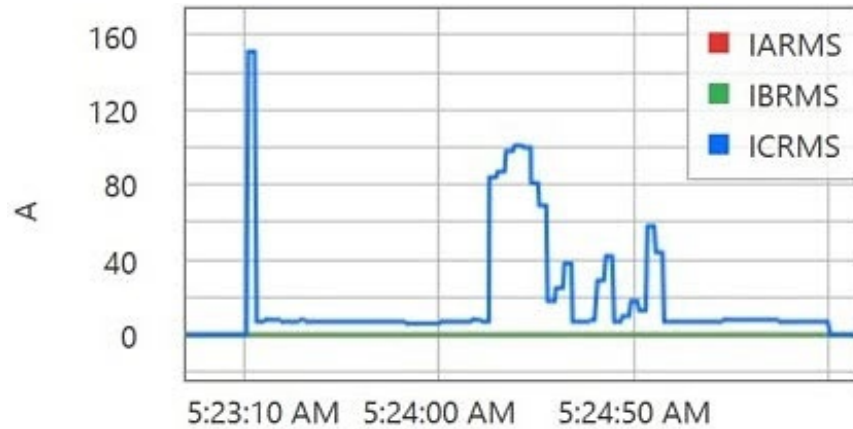


Multiple reclosers detected downed conductor

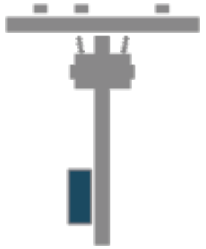
- An upstream circuit breaker relay tripped and reclosed to lock out
- When the tie (Recloser 2) was closed, both reclosers asserted an HIF alarm on Phase C



Current and SDI only on Phase C after tie was closed



Lessons learned



Multiple devices can detect the same HIF



Investigation of current flow and SDI current can help determine which device is closest to an HIF



SDI seen by device attenuates as distance to HIF increases



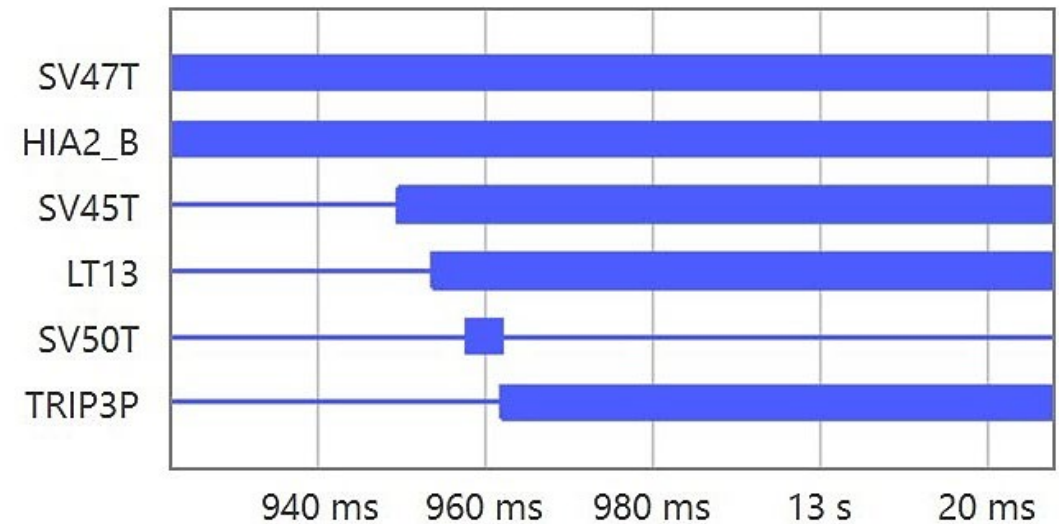
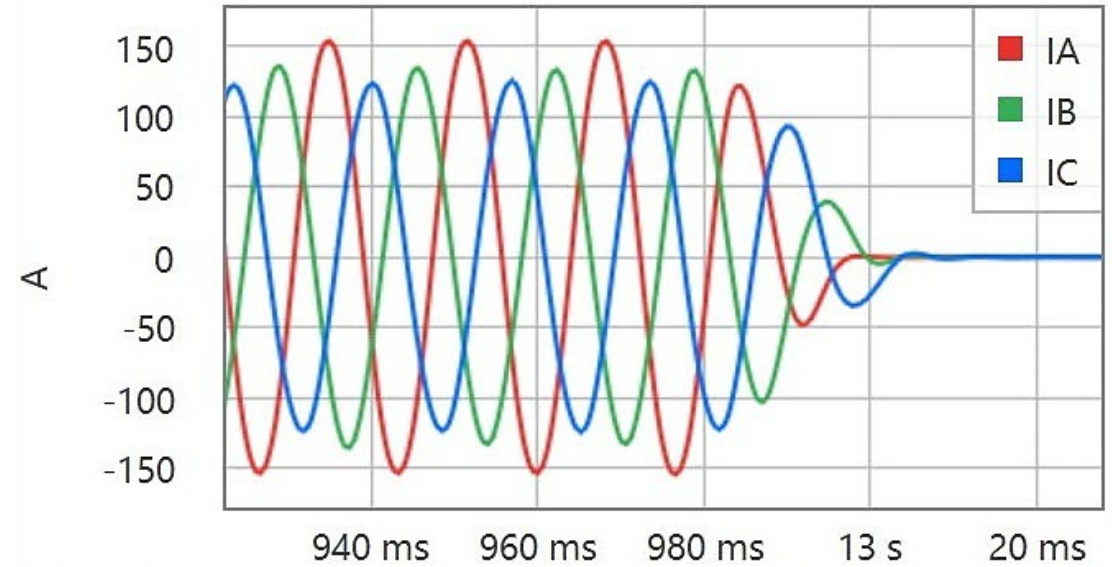
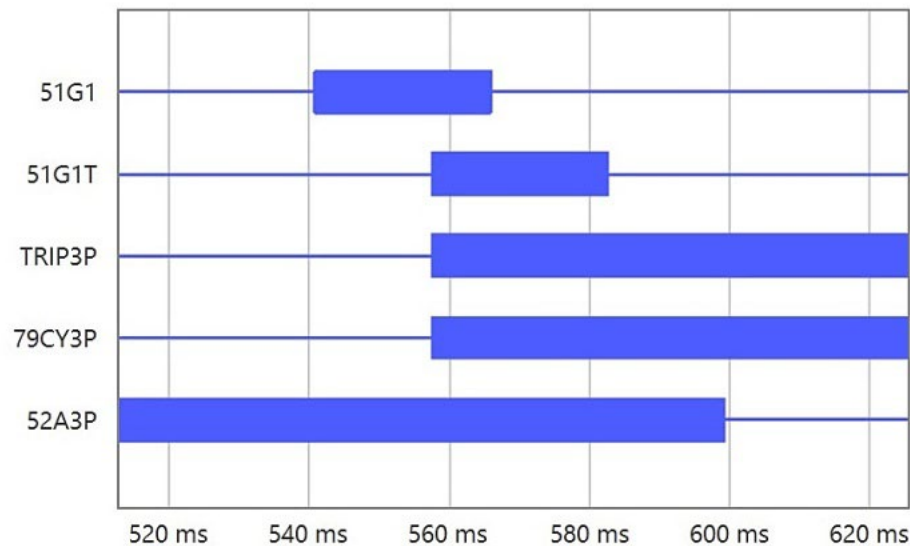
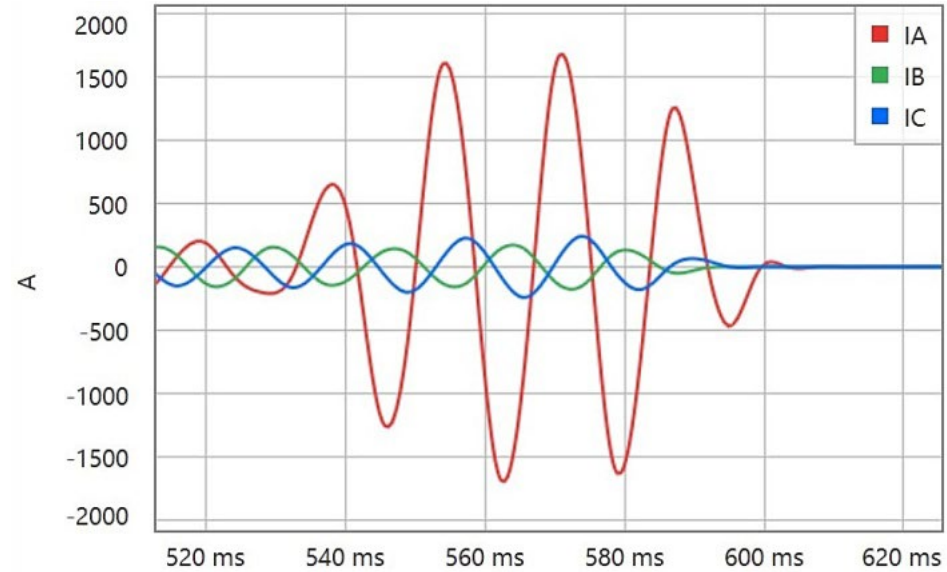
HIF alarm helped call out recloser controller in need of maintenance

HIF algorithm detected failing capacitor bank

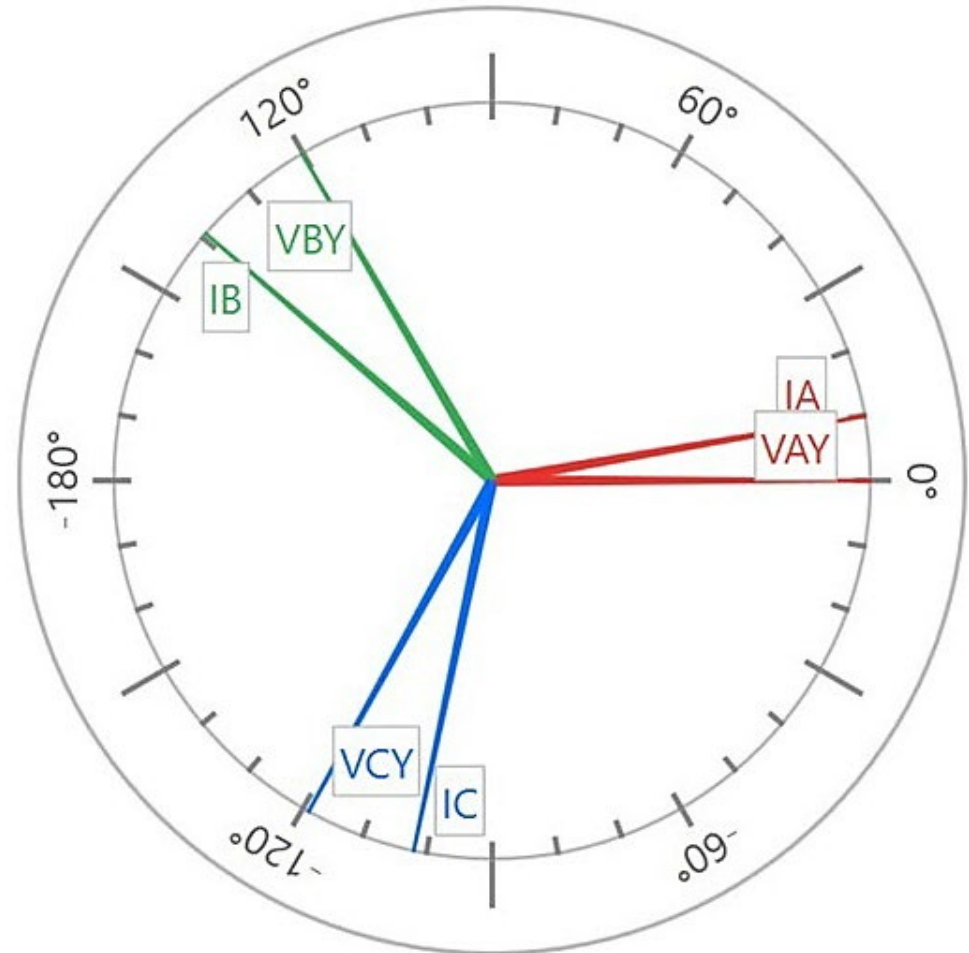
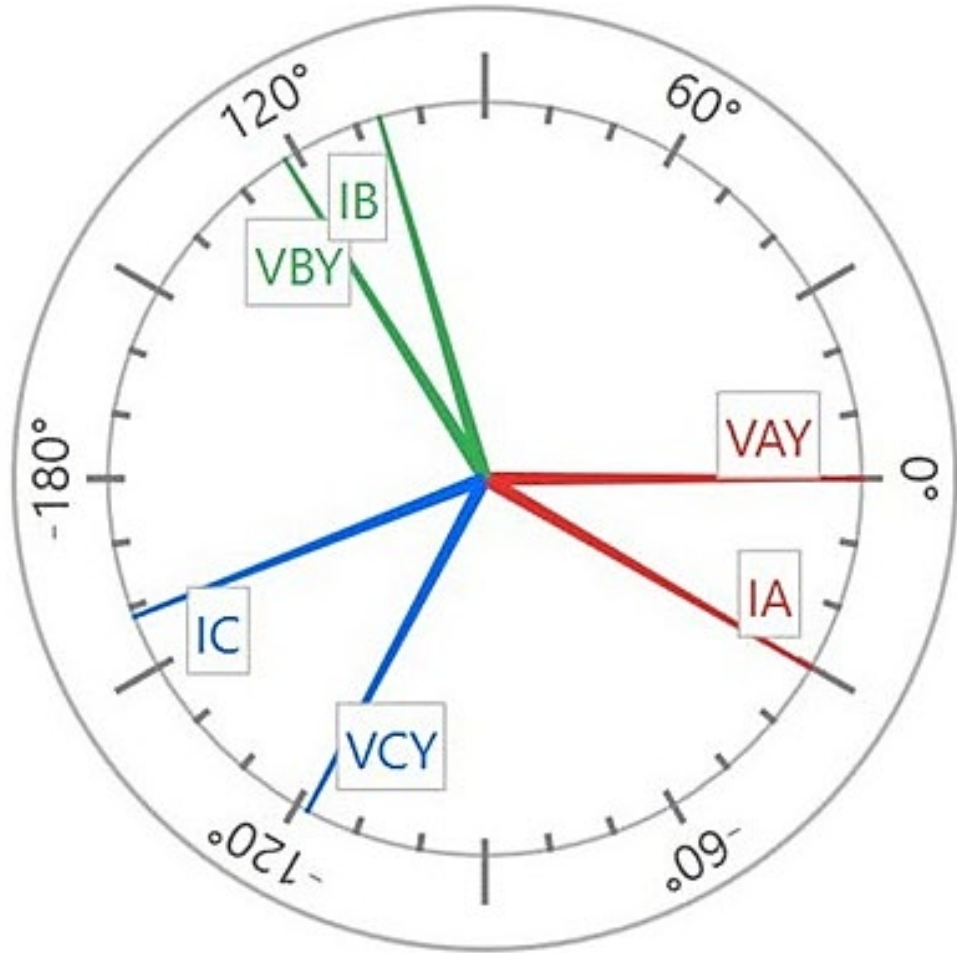
- Recloser controller initially tripped on 51G1T
- Reclose sequence was initiated, which enabled an HIF trip
- Broken throttle on fuse cutout was found



High-current initial trip followed by an HIF trip

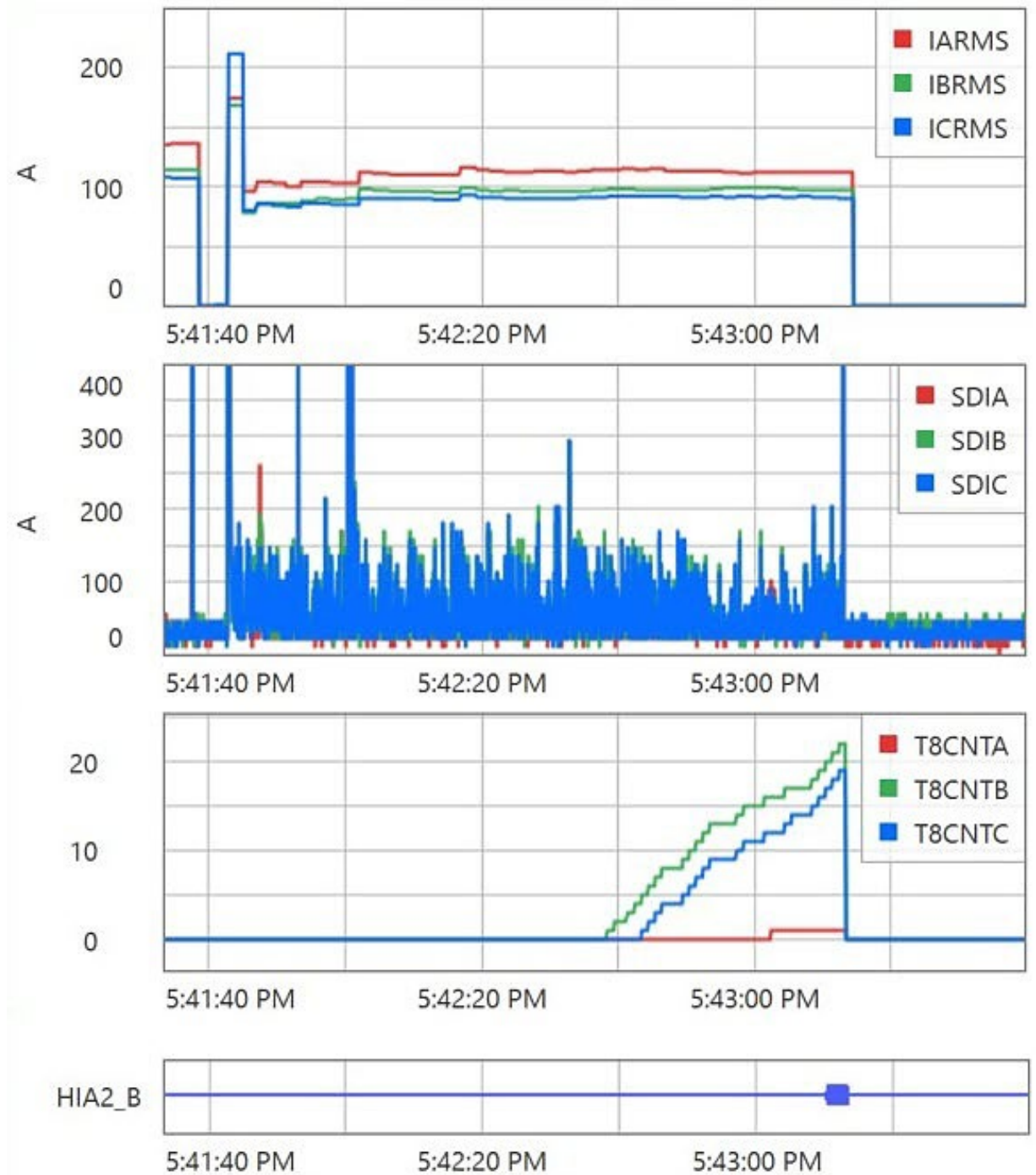


Inductive system changes after reclose



HIF event shows HIA2 output

- HIA2 alarm output caused an HIF trip
- Much lower SDI values but for a longer period



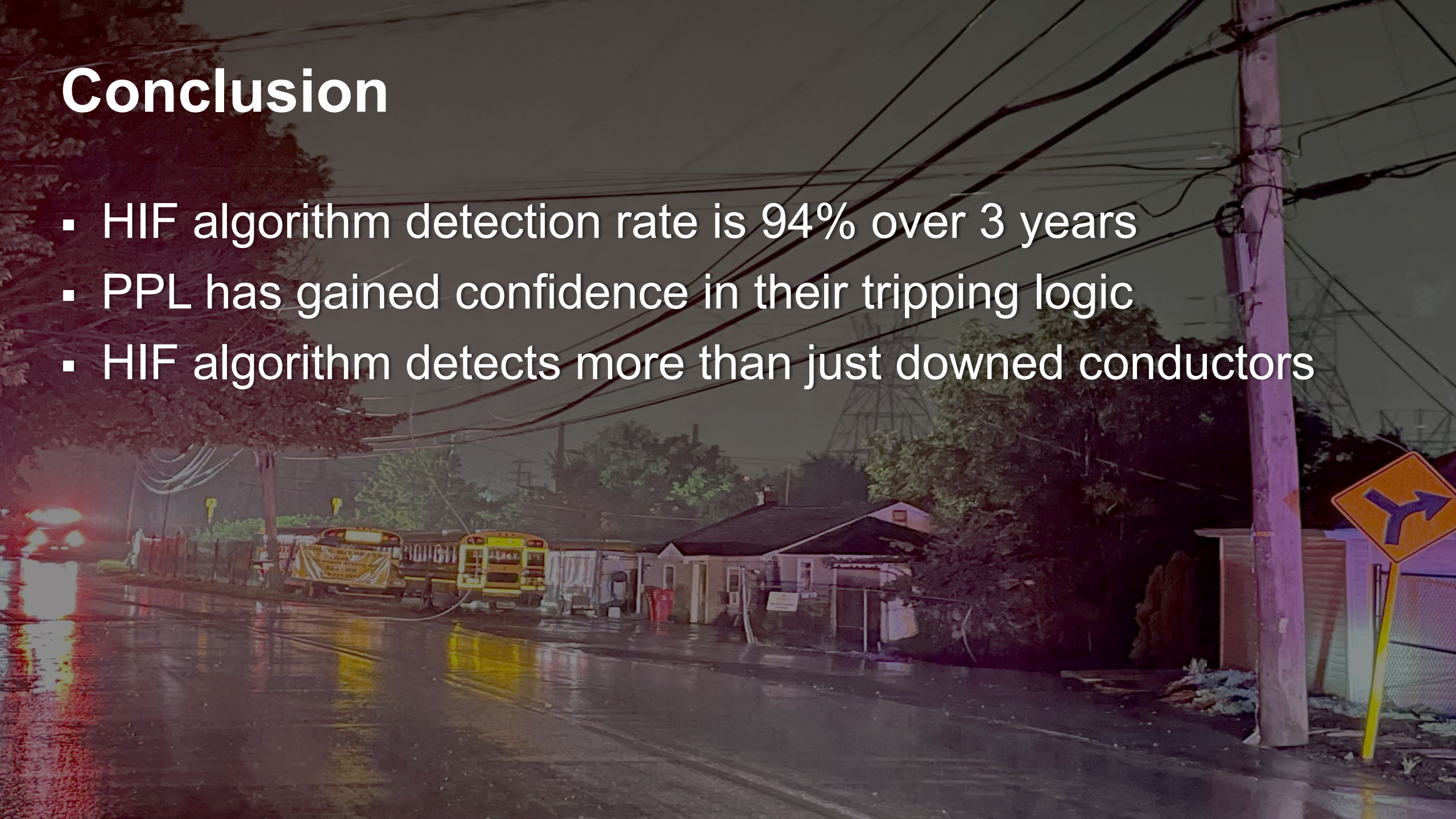
Lessons learned

- HIF tripping logic helped detect and lock out the fault
- Fault likely would have reoccurred causing possible safety risks or further damage
- HIF algorithm could help detect arcing as equipment begins to fail and before a more catastrophic failure



Conclusion

- HIF algorithm detection rate is 94% over 3 years
- PPL has gained confidence in their tripping logic
- HIF algorithm detects more than just downed conductors





Questions?