Distribution Circuit Health Monitoring – Detection of Incipient Failures

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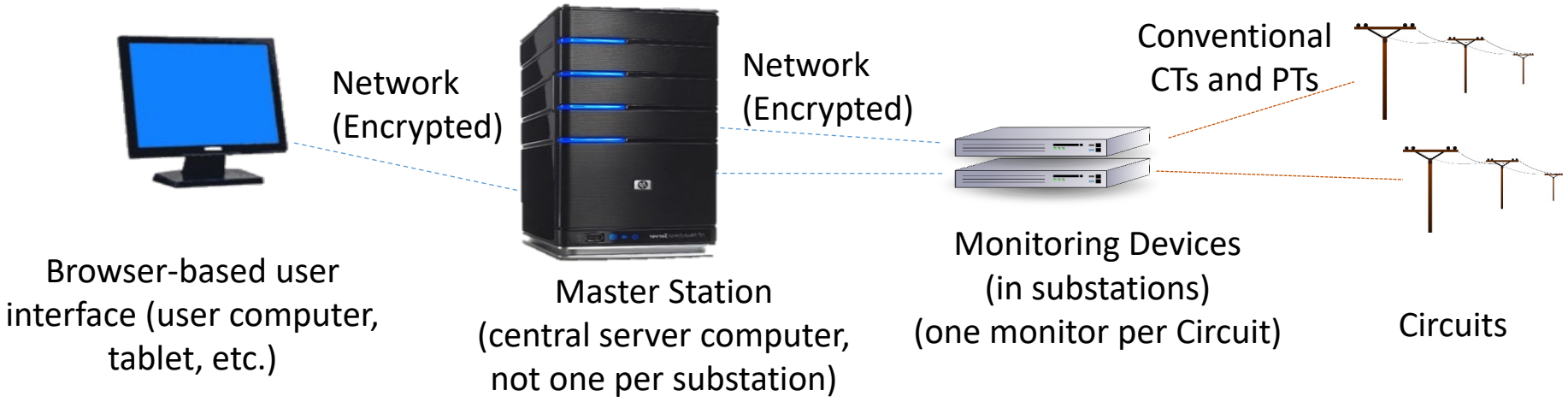
Circuit Health Monitoring

- Many circuits have tens or hundreds of line miles of exposure and thousands of components.
- Circuits give decades of service, but failures occur, from time to time, because of structural failures, external insult, and equipment failures.
  - This presentation addresses equipment failures that have electrically detectable incipient-failure periods.

Background: What Does “Incipient” Mean?

- Incipient failure: any early-stage failure that, left uncorrected, will cause a bad thing in the future. This is a working definition, not Webster’s.
  - It’s about looking forward to what will happen in the future, not about what happened in the past.
- Myth: “If it draws high current, it’s not incipient.”
  - Reality: some incipient failures are low-current, others high-current.
- Incipient periods can range from minutes to months, occasionally longer.

Background: Data for Case Study



This monitoring system provides high resolution, sensitive triggering, and long records. It is installed on more than 600 circuits and detected the field case discussed in this presentation.

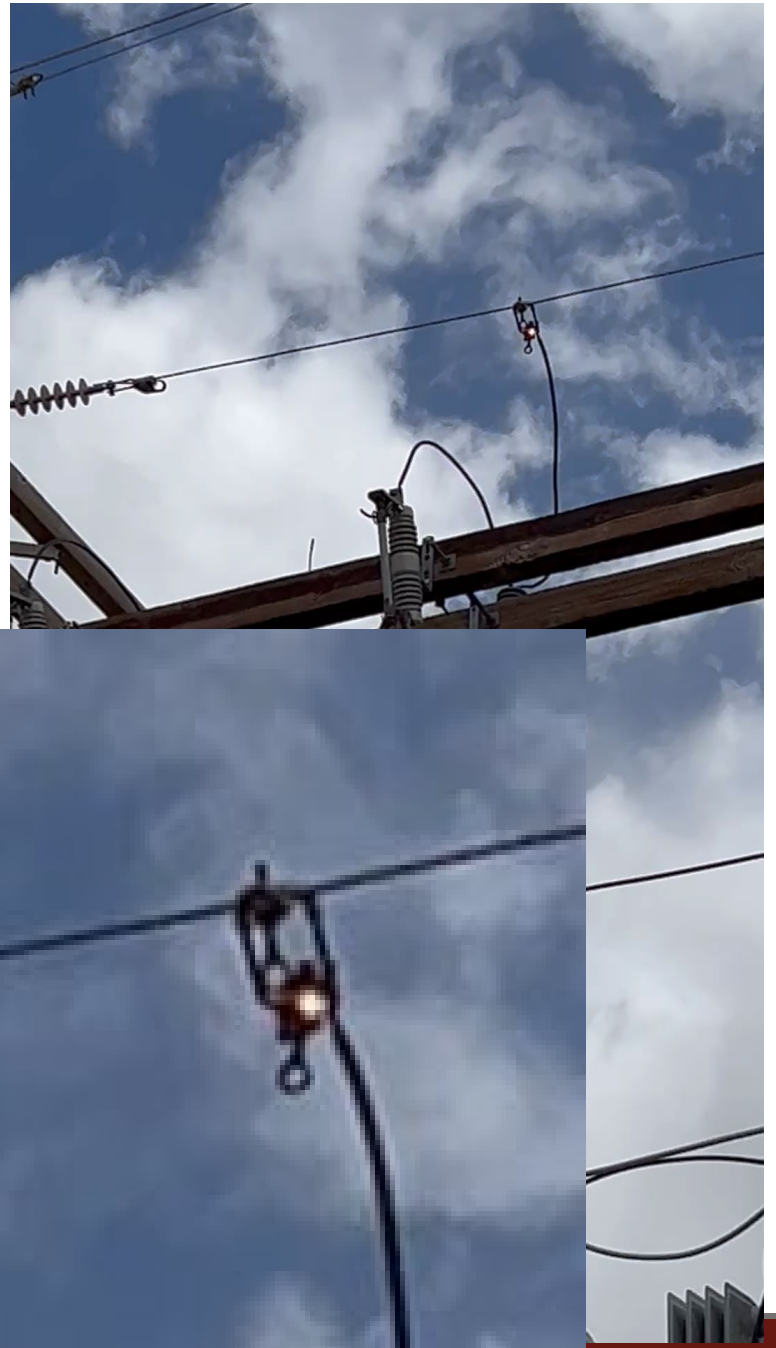
Illustrative Case Studies

- Two cases
  - One low-current
  - One high-current
- Both incipient
- Both detected and acted upon using the electrical circuit health monitoring system

Hotline Clamp (Series Arcing)

Case Study 1 (Low-Current Precursors)

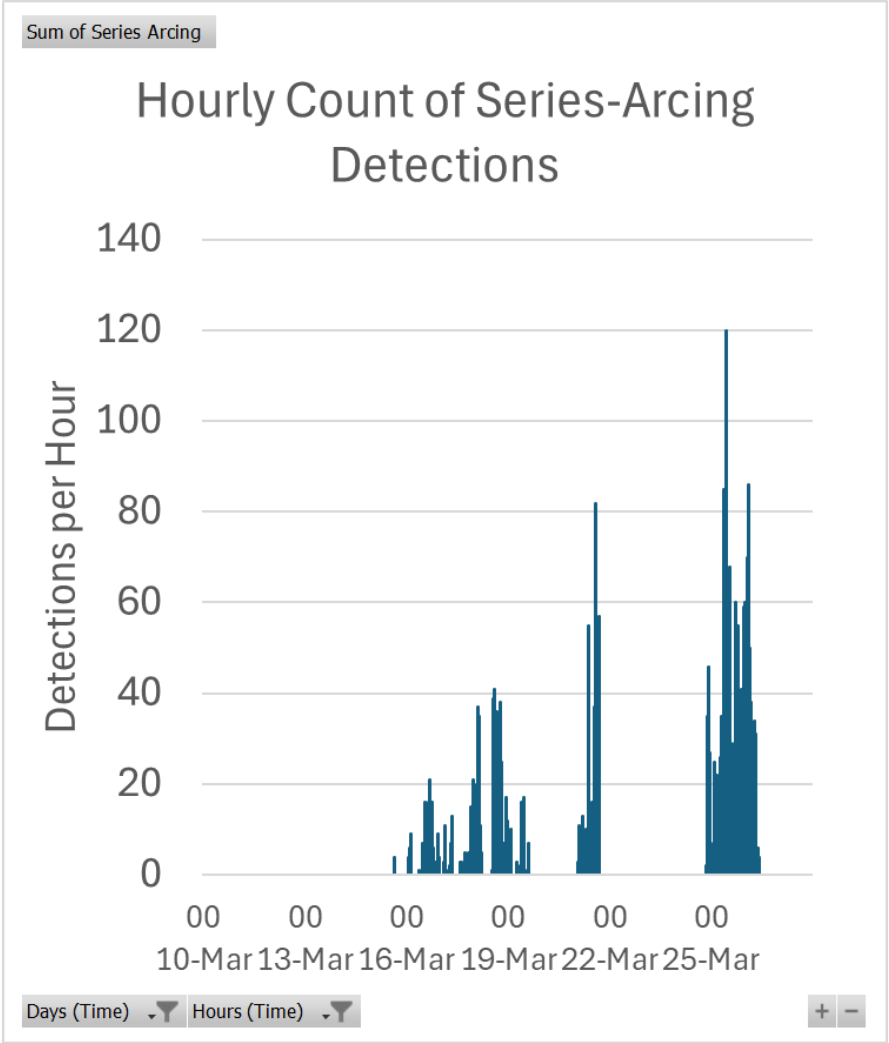
- This video shows (barely!) arcing in a hotline clamp.
- The monitoring system detected this, and the company patrolled, located, and repaired it.
- The clamp was serving oilfield production load. Its failure would have affected production, in addition to fire risk and potential collateral damage.
- At no time did any conventional system (e.g., relay, SCADA) provide any notice.
- Takeaway: Health monitoring enabled improved reliability and reduced risk.



Hotline Clamp (Series Arcing)

Case Study 1 (Low-Current Precursors)

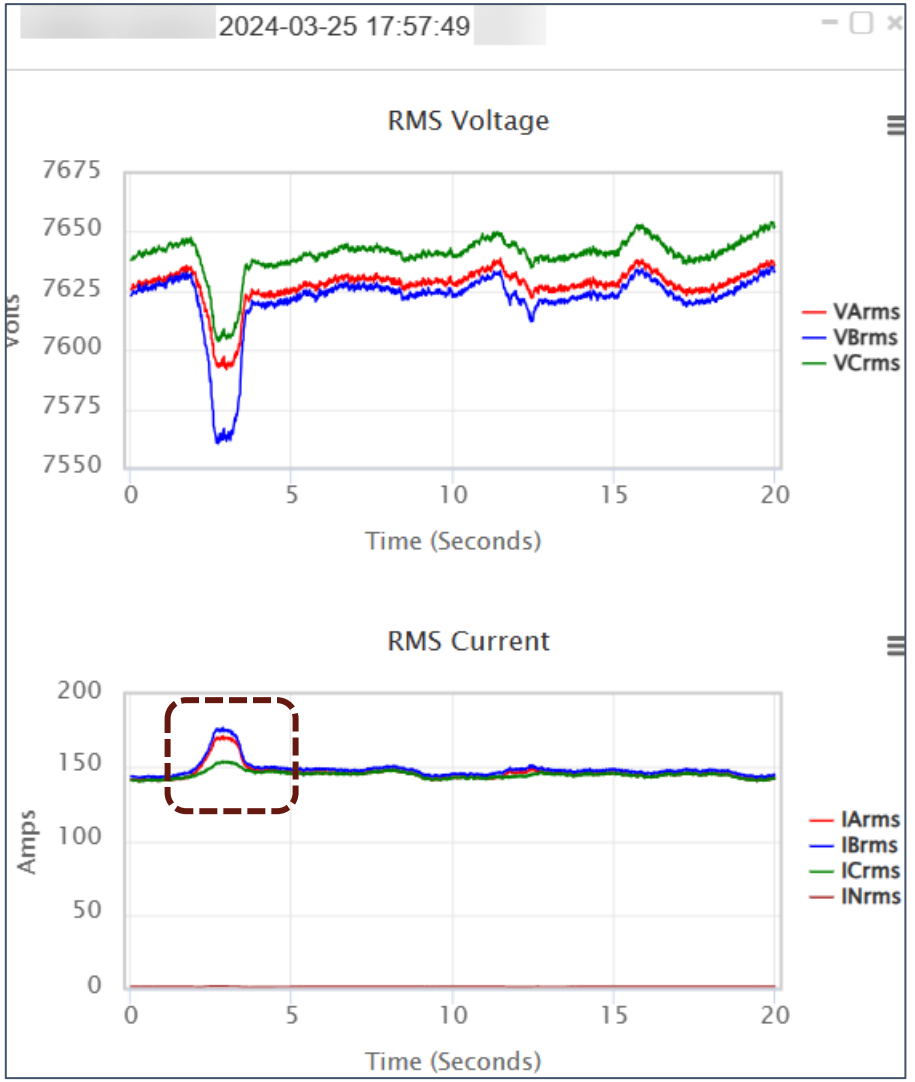
- This series-arcing case, from first detection to repair, spanned eleven days.
- A characteristic of some incipient failures is intermittency. This graph shows hourly counts of series-arcing events detected hourly by the monitoring system.
- Note multi-hour/multi-day quiescent periods.
- In this case, the local crew attributed the intermittency to windy conditions that caused mechanical movement of the associated wires.



Hotline Clamp (Series Arcing)

Case Study 1 (Low-Current Precursors)

- This 20-second recording shows the current during one of the series-arcing “surges.”
  - The monitor is at the substation, so the current includes 145 amps of load current, plus the series-arcing “surge.”
  - (There is a second, smaller “surge” near t=12s.)
- The series-arcing signature is detectable from the substation but would not be picked up by relays, SCADA, etc.



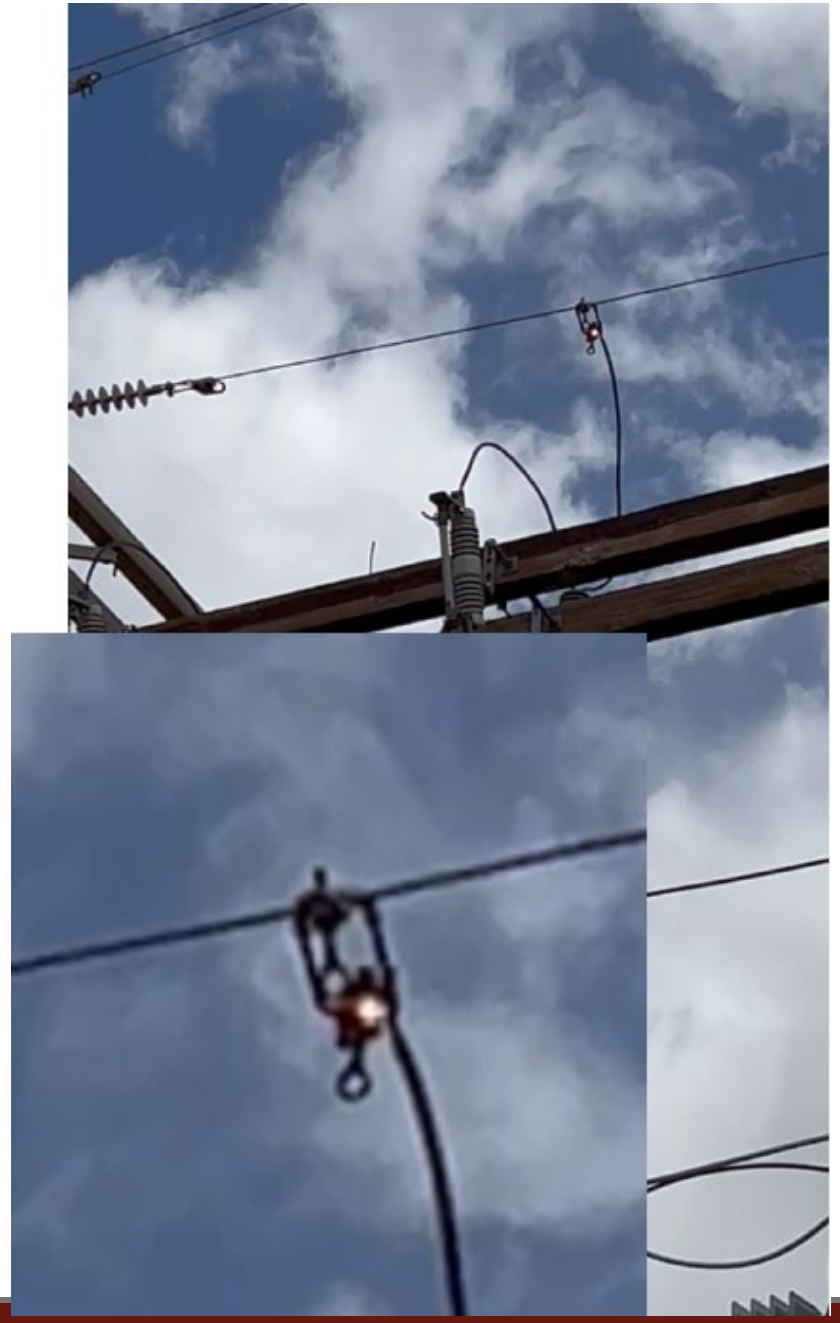
Note: This graph displays 1/cycle RMS to give the “big picture,” but the monitoring system records and preserves data at the full, original 256 samples/cycle. Software algorithms for recognizing this as series arcing analyze the high-fidelity 256/cycle data.

Hotline Clamp (Series Arcing)

Case Study 1 (Low-Current Precursors)

<u>Conclusions</u>

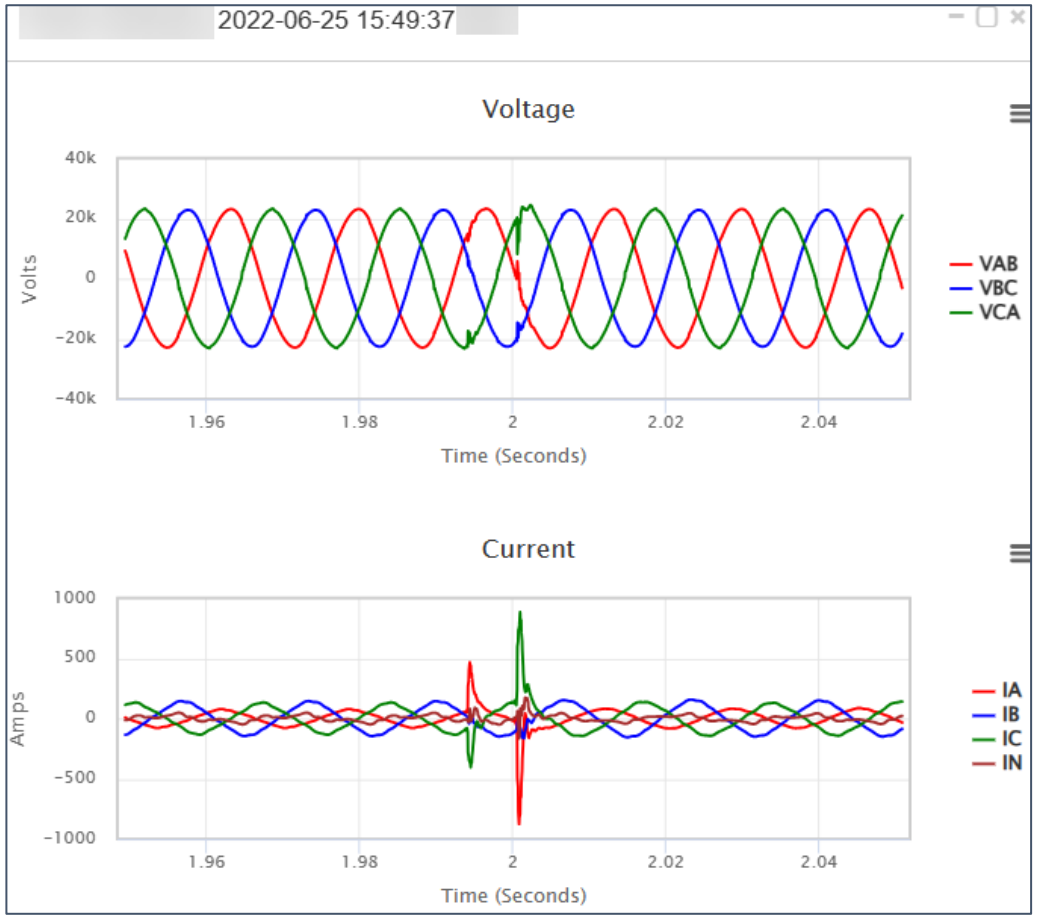
- Some failures experience incipient periods.
  - Some, like this clamp, create recognizable signatures, but they are too small for conventional detection.
- Final failure of a clamp can …
  - Affect reliability
  - Break conductor
  - Cause fire
  - Cause shock hazard
  - Require emergency repairs
- Knowledge of circuit health is the without-which-nothing for proactive repairs.



Capacitor Vacuum Switch

Case Study 2 (High-Current Precursors)

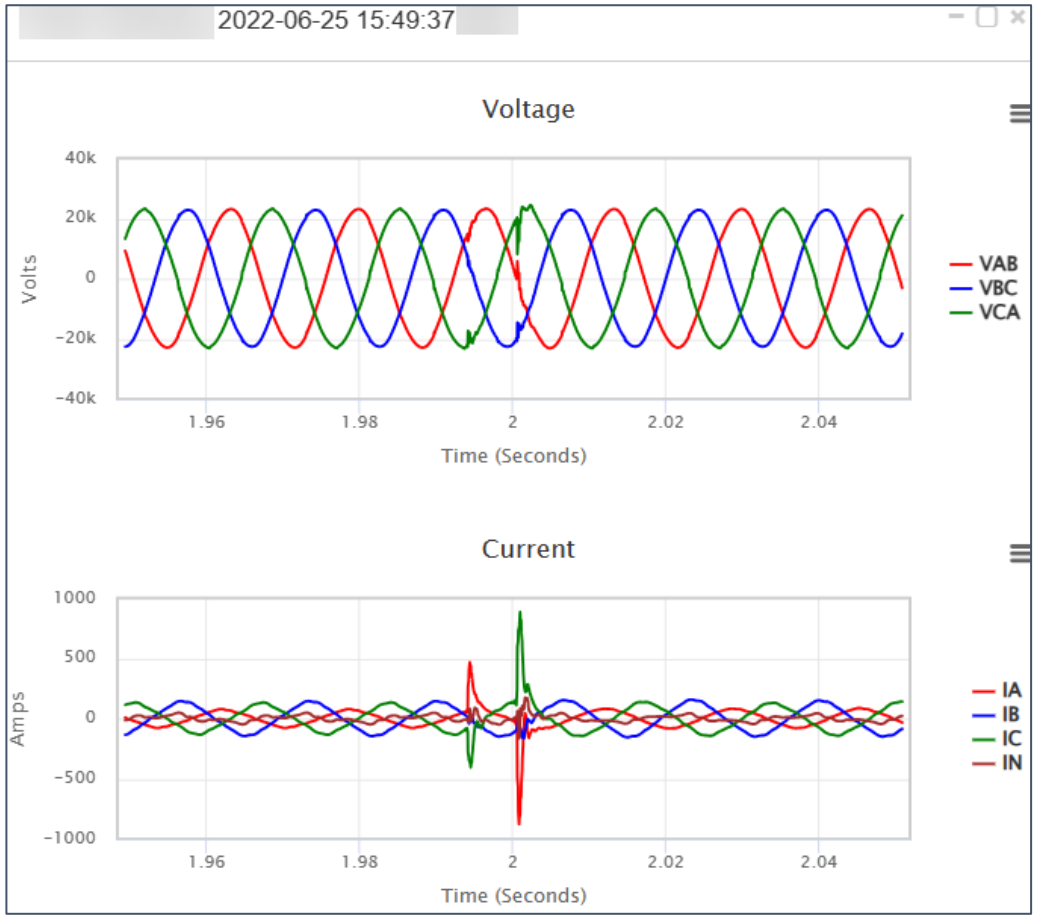
- Partial loss of vacuum in a capacitor bank switch results in pulses like these.
- Pulses have significant magnitude but short duration (here, 850 amps but just 1 milliseconds).
  - The illustrated case caused 241 pulses over a period of six weeks.
  - Protection never operated.
  - No conventional system (relays, SCADA, centralized capacitor dispatch system, …) provided notice of any problem.



Capacitor Vacuum Switch

Case Study 2 (High-Current Precursors)

- The pulses create a pattern unique to partial vacuum loss in a capacitor bank switch.
- Circuit health monitoring alerted the circuit owner with specificity: compromised vacuum switch on an ungrounded 1200 kvar capacitor bank.
- The circuit owner readily identified the bank and made repairs, without outage, fire, explosion, etc.

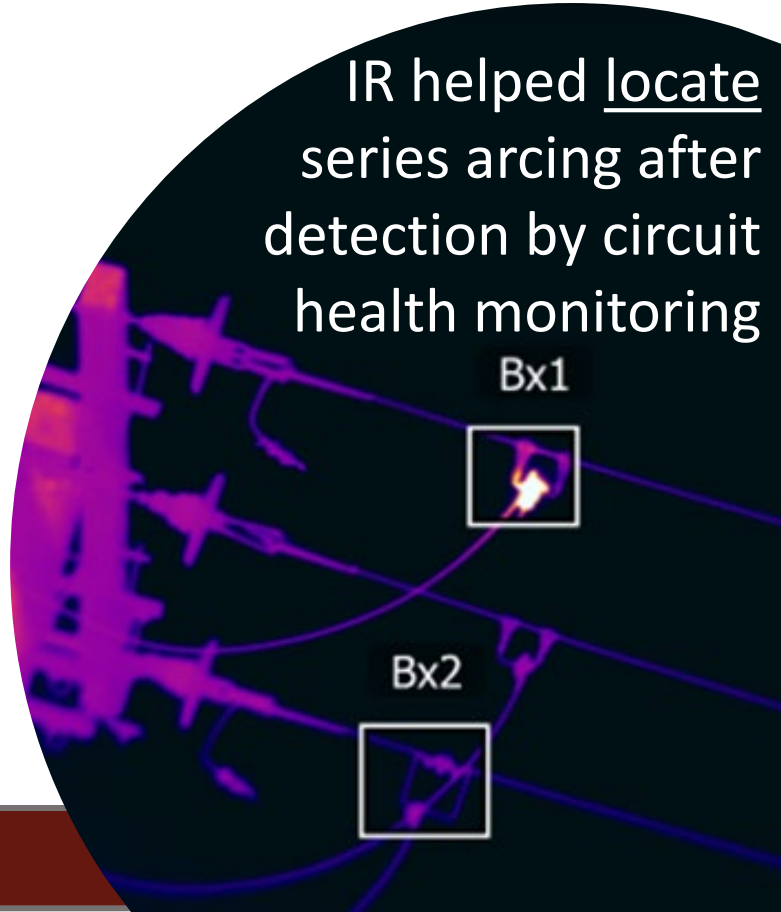


Capacitor Vacuum Switch

Case Study 2 (High-Current Precursors)

- By contrast, a similarly compromised-vacuum switch on another capacitor bank went to final failure (i.e., exploded!).
- Consequences included
  - Exploded vacuum bottle
    - The circled area of the photo shows that the top portion of the vacuum switch is gone.
  - Collateral damage to other poletop hardware
  - Charring (fire risk)
  - Full-circuit outage

Continuous circuit health monitoring can provide early warning for a variety of incipient conditions and enable detection, location, and timely repair, to reduce outages, collateral damage, safety hazards, and ignition risks.



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