



Detecting and Responding to Incipient Failures on Distribution Circuits

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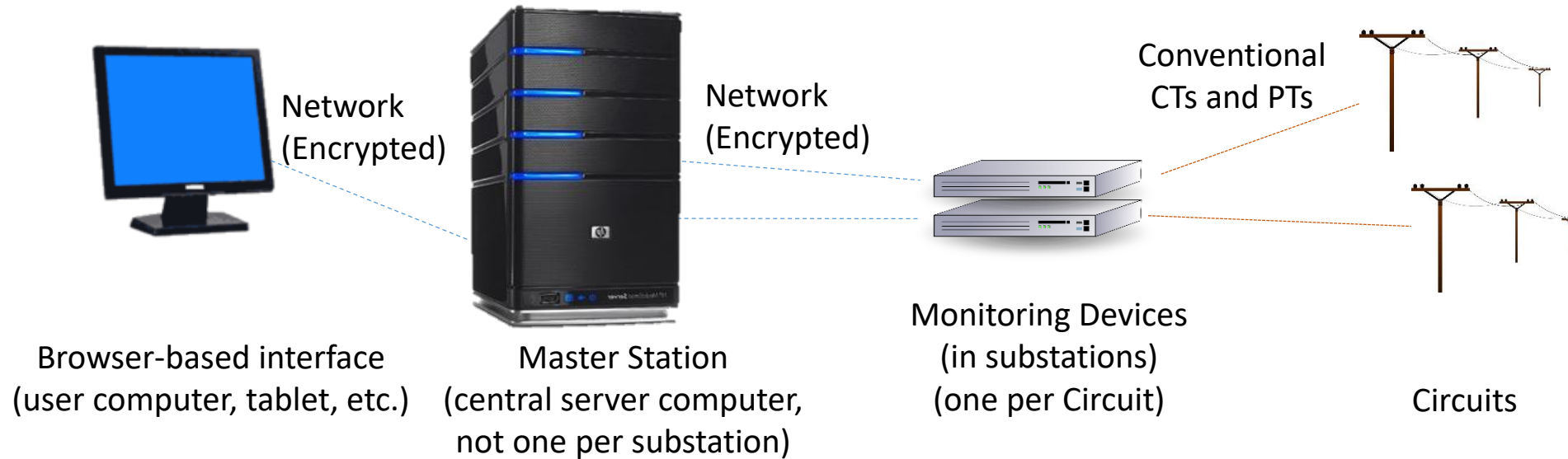


Four incipient failures. None caused outages. All were detected, located, and responded to in a timely way, thus avoiding potentially severe consequences. But accomplishing this requires new, appropriate response procedures.

Texas A&M's Incipient Failure Detection Technology

- EPRI sponsored Texas A&M's initial work in incipient failure detection, beginning in 1997, as a successor to Texas A&M's work on high-impedance fault detection.
- Real-time algorithms were developed based on high-fidelity CT and PT data of in-service circuits during routine operations, not simulation or staged events.
- The system uses sophisticated triggering, recording, and software algorithms to report line events, including incipient failures, generally within two minutes.
 - Monitoring currently is installed on ~550 circuits. The database continues to expand and currently has 1900 circuit-years.
- Texas A&M works collaboratively with utilities that use the monitoring system, to develop (bespoke) best practices for detecting, locating, and responding.
- Ongoing interactions and feedback enable algorithm enhancements.

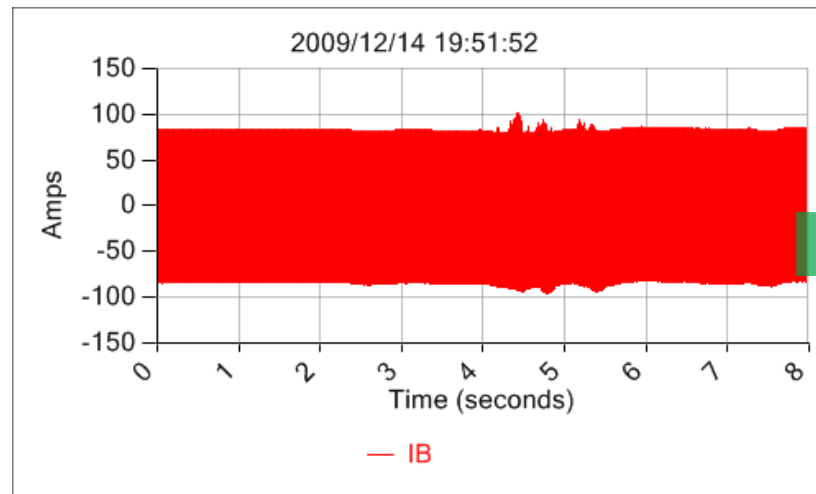
Monitoring System Architecture



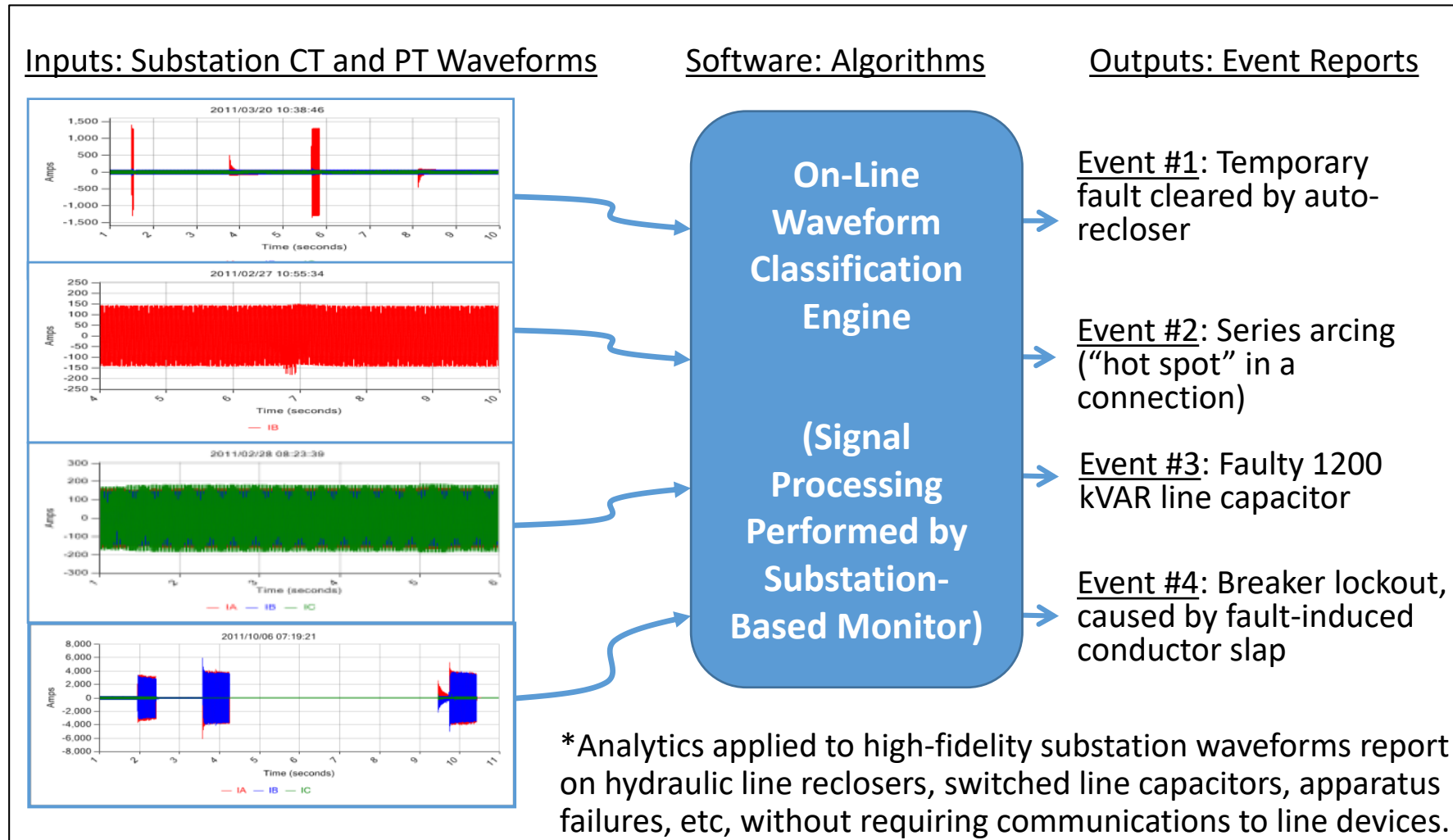
Each substation-installed monitoring device covers an entire circuit 24x7 by analyzing conventional CT and PT waveforms with advanced software and sending results to the central Master Station. Personnel access reports via a browser-based website provided by the Master Station server.

Basic Principle: Waveforms Contain Useful Information

- Graph shows line current recorded during routine operations, with a few amps “modulated” by a failing clamp signature.
- Magnitudes are too low for conventional detection.
- Left uncorrected, such a condition can cause an outage or even a broken conductor. Early correction avoids these consequences.

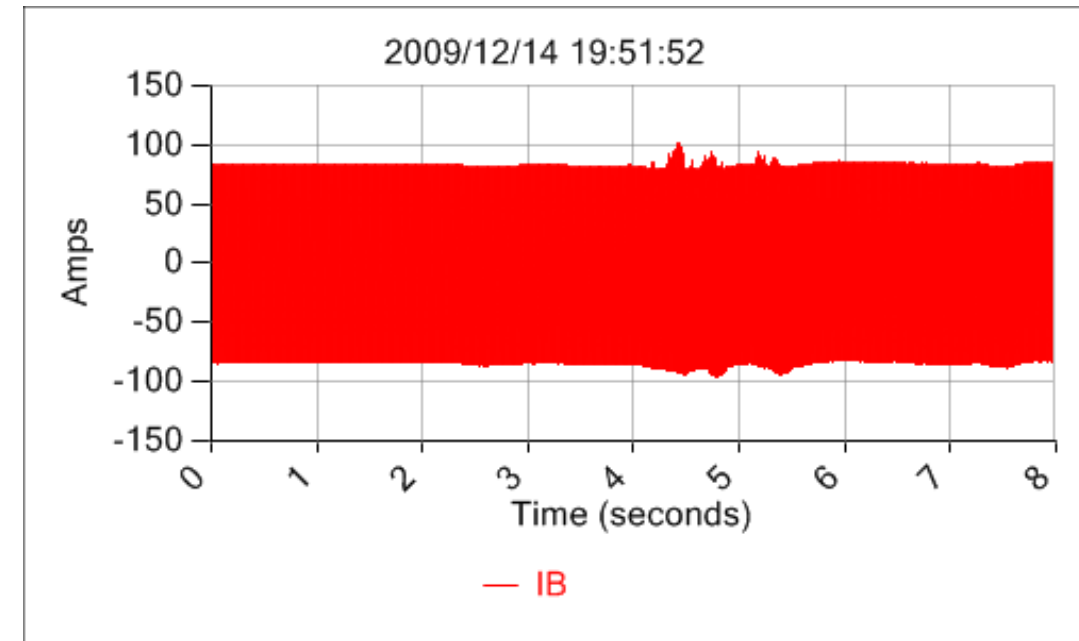


Waveform Classification – Behind the Scenes



Data Requirements

- Hardware (monitoring devices in substations)
 - 18-19 ENOB (effective number of bits) at 256 samples/cycle
 - Sensitive triggering, even on small variations
 - Long records (seconds, not cycles)
- “Can I run this software on my relay data?”
 - No. Relay waveform data lacks needed fidelity, sensitive triggering, record length,
- This is not a criticism. Relays were designed for protection and do a great job providing that function. They were not designed to do things they were not designed to do.
 - Similar comments apply to PQ meters.
- The research team initially sought a commercial off-the-shelf platform (e.g., a relay), but no COTS platform meets data requirements.



A Couple Examples of How Things Are Supposed to Work

Incipient Failure: Substation Switch

- Condition: series arcing in substation switch
- Sequence of events:
 - The monitoring system reported series arcing and provided parameters to target a patrol.
 - Utility located within hours.
 - Repairs were made the same day, with no unplanned outage or catastrophic failure.
- The utility took effective advantage of incipient failure detection, because they responded to reports in a timely way.



Incipient Failure: Separated Jumper

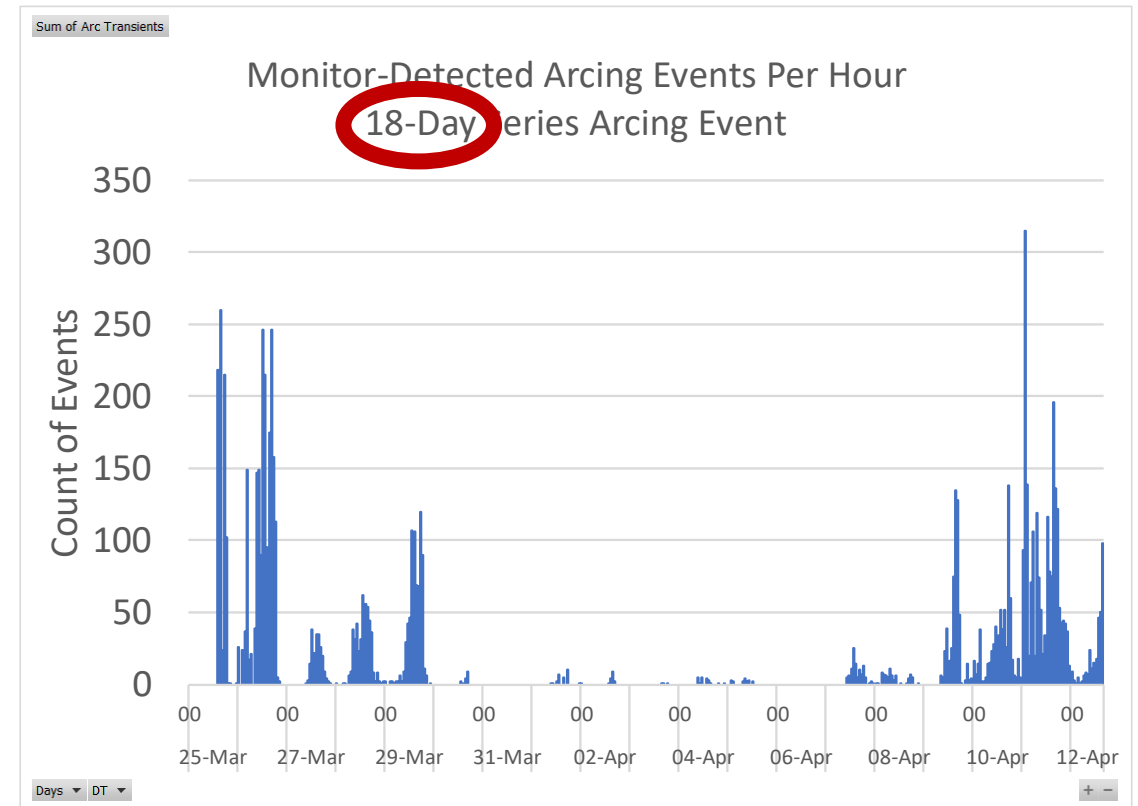
- Condition: primary jumper separated at arrester wrap-around
- Jumper remained in contact and delivering service.
- Sequence of events:
 - The monitoring system reported series arcing.
 - Utility used PLC-based meters to locate specific xfmr.
 - Repair was made within hours. No unplanned outage.
- The utility was able to take effective advantage of incipient failure detection, because they had developed a process for timely response.



An Example of Unrealized Potential

Incipient Failure: Bushing Connection

- Condition: separated connection at primary transformer bushing
- Sequence of events:
 - The monitoring system reported series arcing.
 - Utility used AMI meters to locate the specific transformer.
 - But repair was NOT made.
 - Connection failed after 18 days.
- This was a process failure, not a technology failure.



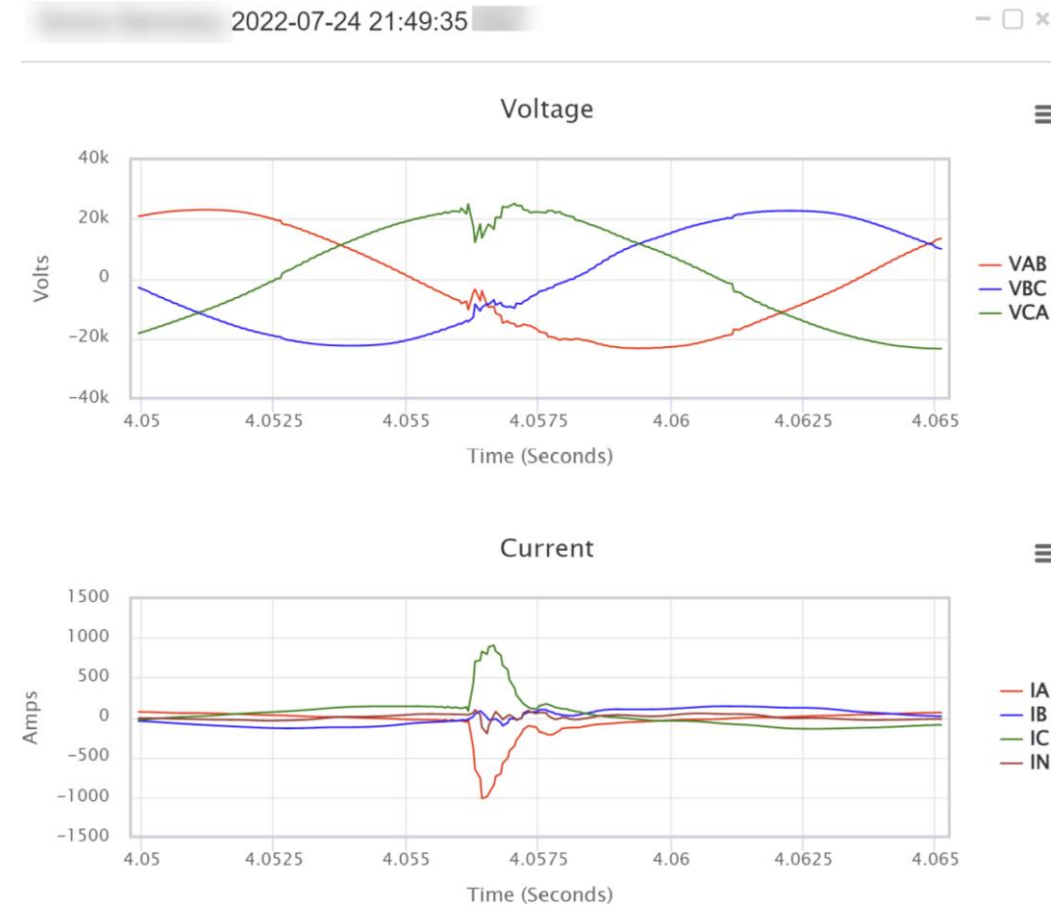
Another observation: This case also illustrates how series arcing often does NOT accelerate as failure approaches.

Another Success

(Incipient Condition with Higher-Current Precursors)

Incipient Failure: Capacitor Vacuum Switch

- Condition: partial loss of vacuum in a capacitor bank switch
- Partial loss of vacuum enables intermittent “leakage pulses.”
- Pulses have significant magnitude but short duration (here, 2 ms).
 - Incipient is not synonymous with low current!
 - “Incipient” means a condition that, left uncorrected, will cause a bad outcome.



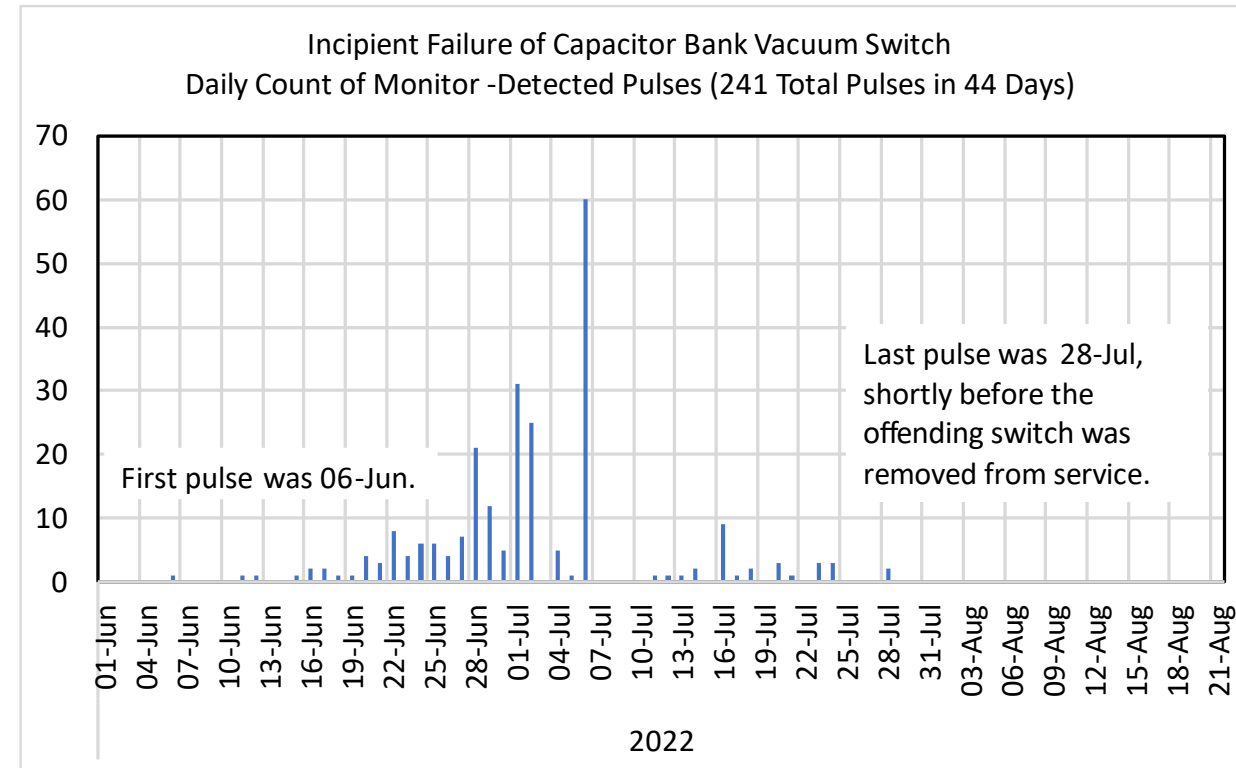
Incipient Failure: Capacitor Vacuum Switch

- The monitoring system reported 241 pulses over a period of 44 days.
- The automated software diagnosed some pulses just as short-lived faults.
- But others as capacitor restrike of a 1200 kvar bank.
- The circuit has two 1200 kvar banks and a centralized cap dispatch system.
- Correlating event timestamps with capacitor switching times definitively identified the offending bank.

Capacitor restrike (severe)	2022-07-24 21:49:35
Capacitor restrike (severe)	2022-07-23 00:19:27
Capacitor restrike (severe)	2022-07-18 18:49:54
Capacitor restrike (severe)	2022-07-17 00:19:59
Capacitor restrike (severe)	2022-07-14 23:49:30
Capacitor restrike	2022-07-13 07:49:31
Capacitor restrike	2022-07-04 00:49:36
Capacitor restrike (severe)	2022-07-01 19:19:42
Capacitor restrike (severe)	2022-07-01 04:49:37
Capacitor restrike	2022-06-30 13:19:32
Capacitor restrike	2022-06-29 19:49:48
Capacitor restrike	2022-06-29 05:49:43
Capacitor restrike (severe)	2022-06-28 14:49:43

Incipient Failure: Capacitor Vacuum Switch

- The identified bank was switched off.
- The monitoring system was used to confirm that the pulses stopped.
- Again contrary to intuition, the precursor timeline shows that this event did not “accelerate” to failure.
- This incipient failure had high-magnitude precursors, but the utility’s conventional systems and business-as-usual processes detected nothing.



Takeaways

- Many incipient failures now can be detected.
- Texas A&M has developed technology that reports multiple types of incipient failure. Some give minutes of warning; others give weeks or months.
- Other technologies often are necessary for location (synergy).
- Knowing of an incipient failure, and even knowing where it is, is insufficient to recognize benefit. Effective, timely response is needed.
 - Certain long-established procedures may need to be re-thought.