

Detection of Pre-Failure of Capacitor Vacuum Switch

Real World Experiences Session
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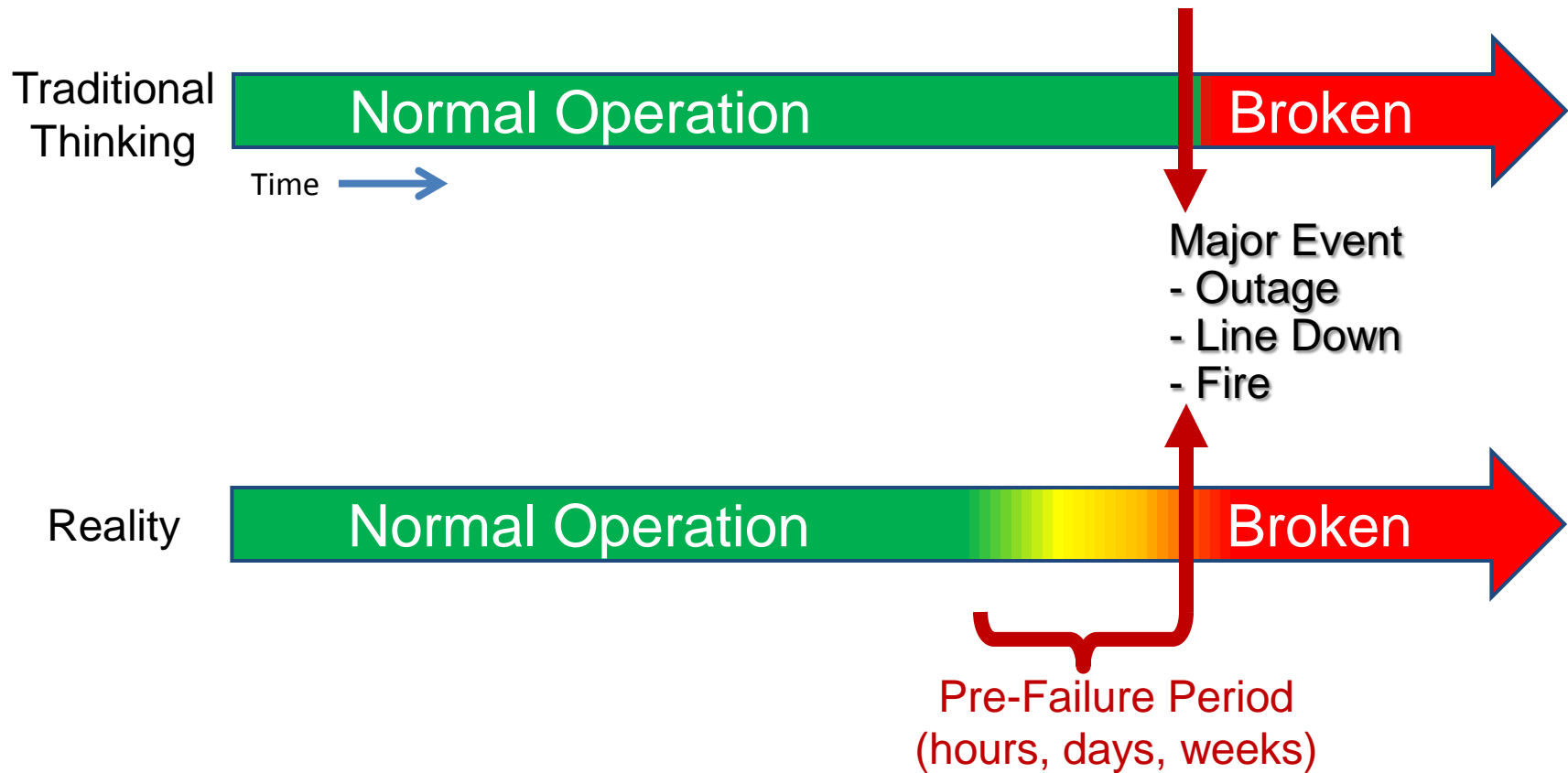
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Presentation Outline

Background Information..... Carl Benner, Texas A&M

Discussion of CenterPoint Event..... Jesus Guerra, CenterPoint Energy

Electrical Feeder Operational Paradigms



Detecting pre-failures makes it possible to make repairs before major events occur.

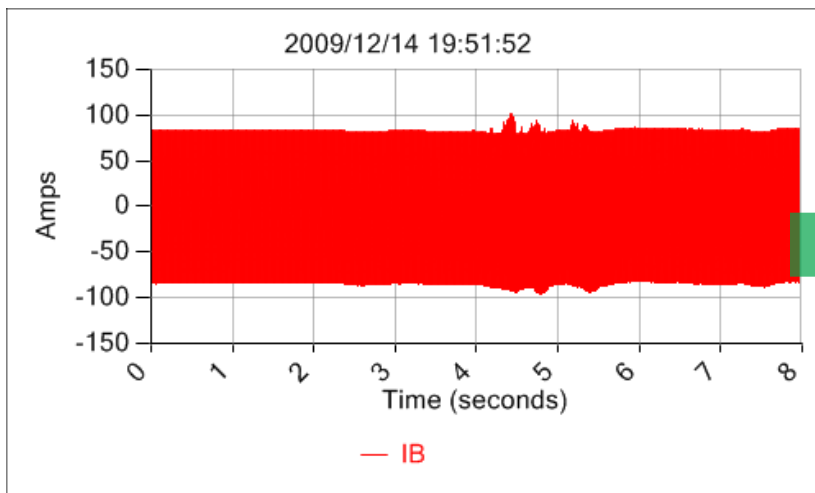
Fundamental Principles of Waveform Analytics

- Feeder-level electrical waveforms represent feeder activity.
- Sophisticated waveform analytics, applied to waveforms of sufficient fidelity, can detect failures, pre-failures, and other feeder events.
 - PQ meters and relays have the same inputs (i.e., CTs and PTs) but do not record data of sufficient fidelity to support DFA functions.
- Waveform analytics also report operations of line devices (reclosers, capacitors, etc.), enabling oversight of those devices, without requiring communications to them.

With support from EPRI and others, Texas A&M has developed an on-line system of waveform analytics. This system, known as DFA Technology, provides situational intelligence that enables improvements in reliability, operational efficiency, and safety.

Measured Example

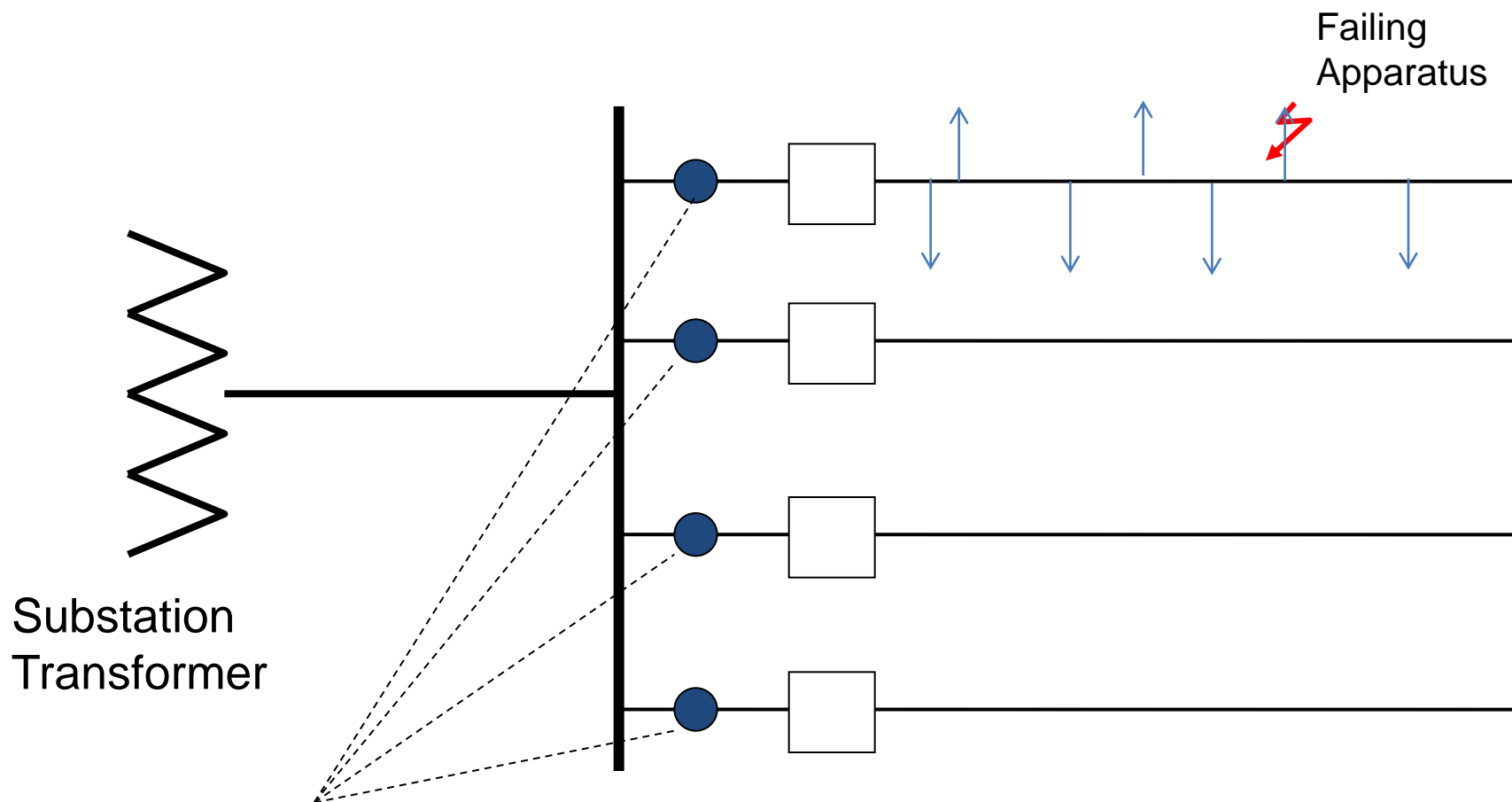
- Graph shows current during “normal” feeder operations.
- Analytics report this specifically as a failing clamp. Failing clamps can degrade service quality and, in extreme cases, burn down lines.
- Conventional technologies do not detect pre-failures such as this one.



On-Line
Waveform
Analytics



Monitoring Topology



High-fidelity DFA devices, connected to conventional CTs and PTs, one per feeder.

CenterPoint Energy Project

- Began DFA trial in 2012
- Instrumented four feeders
 - Two 12.5 kV feeders
 - Two 34.5 kV feeders
- Has detected multiple events
 - Repetitive tree-induced conductor clash that severely damaged conductors
 - Failing line switch
 - Capacitor restrikes
 - Pre-failure of capacitor vacuum switch (to be detailed in today's presentation)
 - Note: This is a partial list



Detailed Use Case

Capacitor Vacuum Switch Pre-Failure

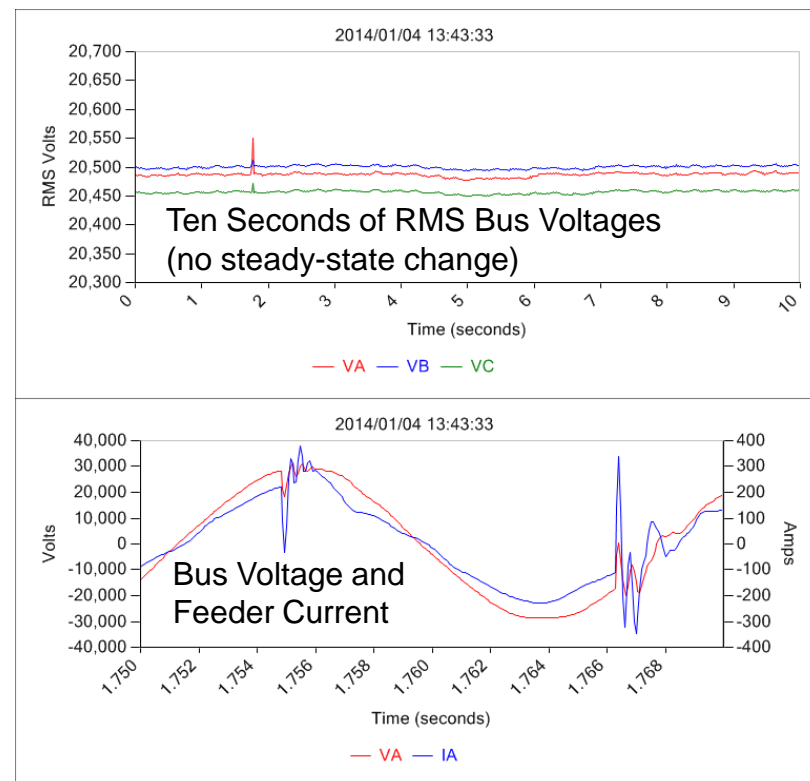
- CenterPoint uses one-way paging to switch feeder capacitors. After each page, the system monitors substation VARs to verify 1) that the bank has switched and 2) that it is balanced.
- On 11/29/2013, a DFA device began detecting unusual transients suggesting pre-failure of a capacitor bank.
- Trouble tickets indicated no problem. CenterPoint and Texas A&M continued to monitor.
- The transient occurred 500 times over the next 2-1/2 months.
- After 2-1/2 months, increasing event activity suggested the problem might be accelerating toward failure, prompting corrective action.

Detailed Use Case

Capacitor Vacuum Switch Pre-Failure (cont'd)

Theory and Analysis

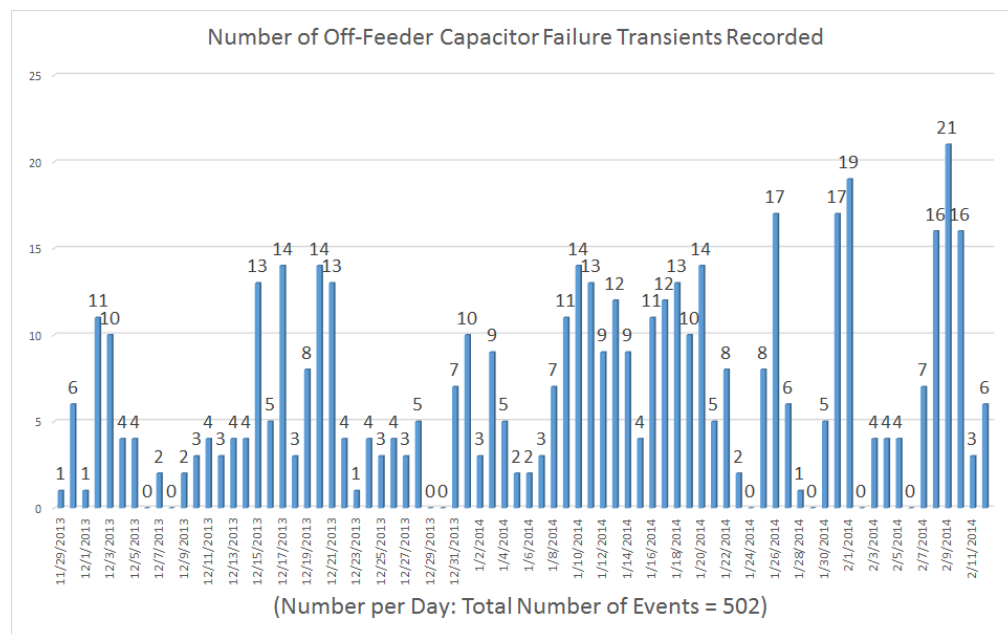
- Normal capacitor switching causes two phenomena.
 - A short-lived high-frequency transient
 - A step change in voltage (yes, even at the bus!)
- Each subject event caused a transient, but no step change.
- This indicates the events were not during switching.
- Each event caused a high-frequency spike in current and voltage.
 - The current and voltage spikes had the same polarity (i.e., when voltage spiked up, current spiked up).
 - This indicated a “reverse” event. For “forward” events, voltage and current spikes have opposing polarities.
 - From the DFA’s perspective, a “reverse” event is one occurring on a different feeder or on the bus itself.



Detailed Use Case

Capacitor Vacuum Switch Pre-Failure (cont'd)

Statistical Analysis #1: Number of transient events recorded per day, during 75-day period.



- Graph shows the number of events on each day (11/29/2013 – 2/12/2014)
- There is no definitive trend.
- “Peaks” weakly suggest a slight increase in activity over time.

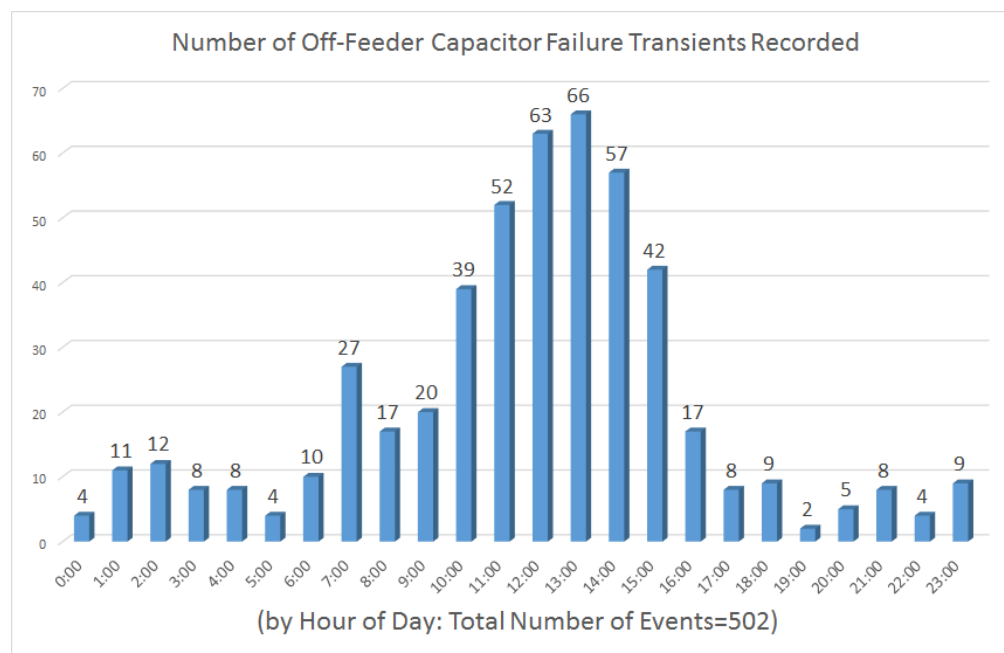
Detailed Use Case

Capacitor Vacuum Switch Pre-Failure (cont'd)

Statistical Analysis #2: Number of transient events recorded as a function of time of day.

Graph shows the frequency of events as a function of time of day, cumulatively for the 75-day period.

- Events occur at all times of day but most frequently during the middle of the day.
- 64% occur during 25% of day. (319 of 502 events between 10:00 and 16:00)
- 47% occur during 17% of day. (238 of 502 events between 11:00 and 15:00)



Detailed Use Case

Capacitor Vacuum Switch Pre-Failure (cont'd)

- On February 14, the utility decided to open the fuses of all five of the feeder's banks to confirm the "pre-failure capacitor bank" diagnosis.
- A crew found an anomaly at the first bank.
 - The bank's "closed" current should be 30 amps.
 - The paging system showed the bank as "open."
 - A hot-stick meter showed 0.7 amps through the "open" switch.
 - First bank's fuses were pulled.
 - Other four banks were left in service.
 - DFA system was watched for five days. Absence of additional transients validated diagnosis.
- The pre-failure switch failed a hi-pot test. A vacuum interrupter expert performed a root cause analysis.

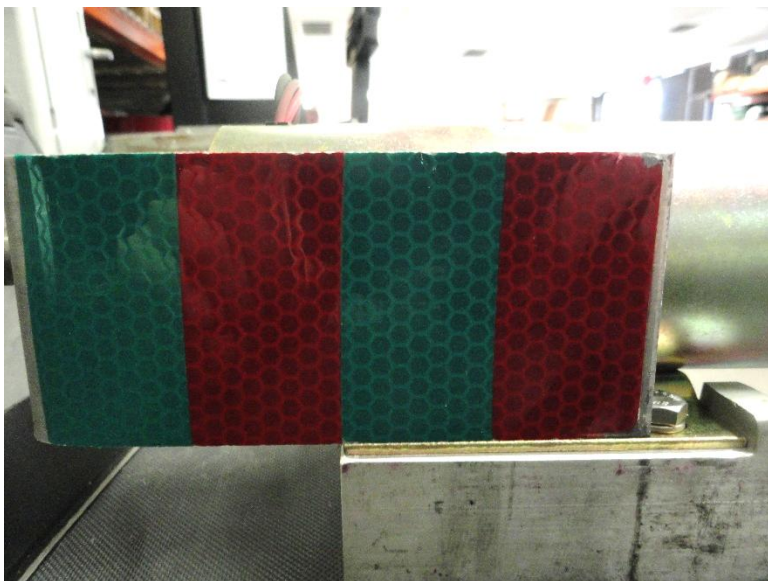


Magnetron-
Based Vacuum
Tester

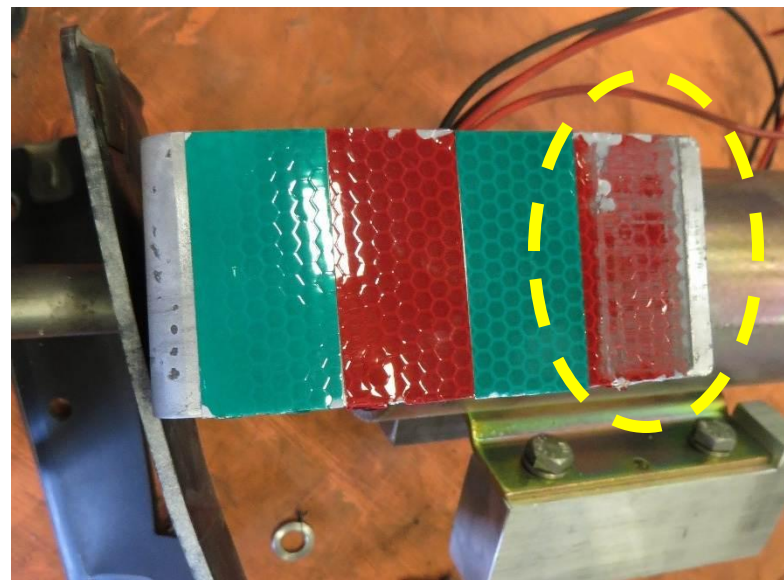


Detailed Use Case

Capacitor Vacuum Switch Pre-Failure (cont'd)



Red/Green Indicator
on Normal Phase

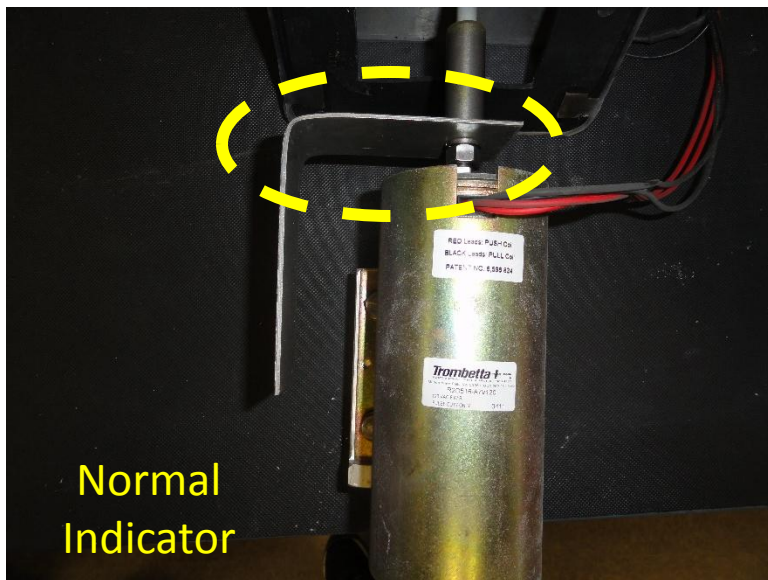


Red/Green Indicator
on Pre-Failure Phase

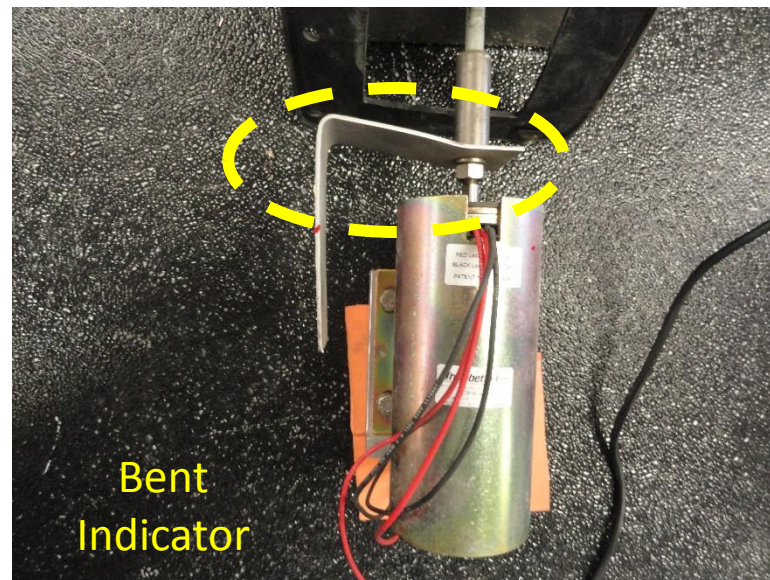
The switch has a sight window with a red/green position indicator. The pre-failure switch's indicator had clear signs of rubbing against the mechanism housing.

Detailed Use Case

Capacitor Vacuum Switch Pre-Failure (cont'd)



Indicator on
Normal Phase

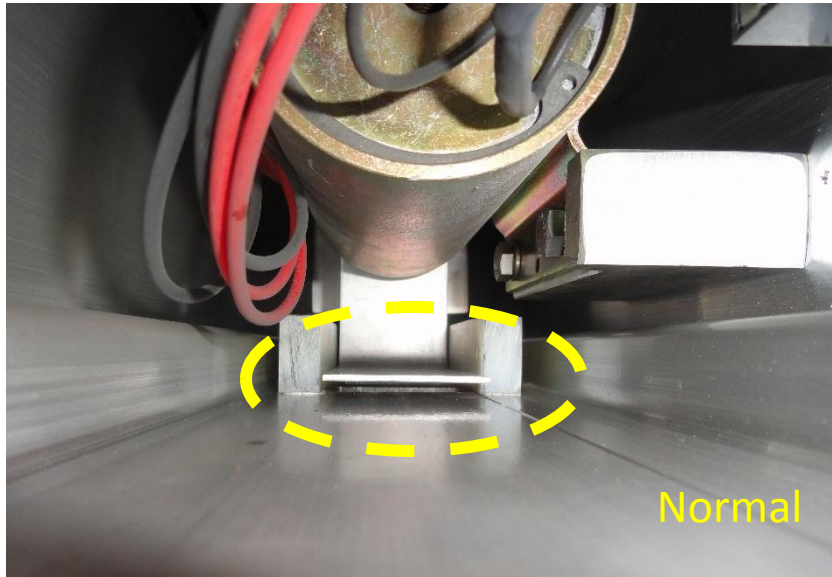


Indicator on
Pre-Failure Phase

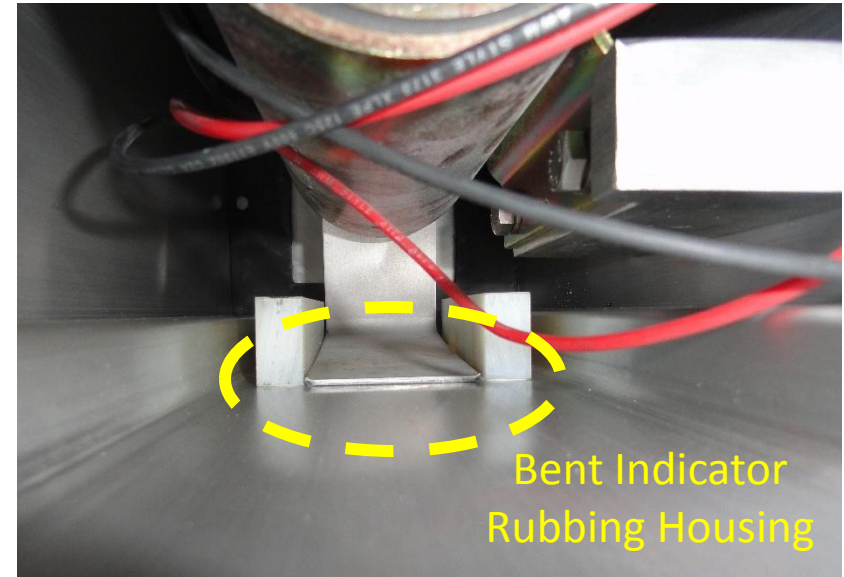
The indicator on the normal phase has an intentional 90-degree bend. The indicator on the pre-failure phase clearly is deformed.

Detailed Use Case

Capacitor Vacuum Switch Pre-Failure (cont'd)



Red/Green Position Indicator
Mechanism on Normal Phase



Red/Green Position Indicator
Mechanism on Pre-Failure Phase

The root cause of the pre-failure was the indicator rubbing and binding, preventing the switch contacts from parting fully. Current (0.7A) flowing through the gap is believed to have caused progressive internal damage to the vacuum interrupter.

Detailed Use Case

Capacitor Vacuum Switch Pre-Failure (cont'd)

Summary and Conclusions

- Vacuum switch failures have multiple potential consequences.
 - Least severe: unbalanced capacitor operation
 - Most severe: rupture of switch or capacitor
- This pre-failure example persisted 2-1/2 months before intervention.
 - Normal operational practices did not and do not detect this kind of pre-failure.
 - Pre-failure detection provided time (in this case, 2-1/2 months) to correct the condition and preempt full failure.
- Waveform analysis provided only notice and opportunity to correct proactively.



Magnetron-
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