Use of Advanced Monitoring Technology to Detect Incipient Failure of Line Equipment

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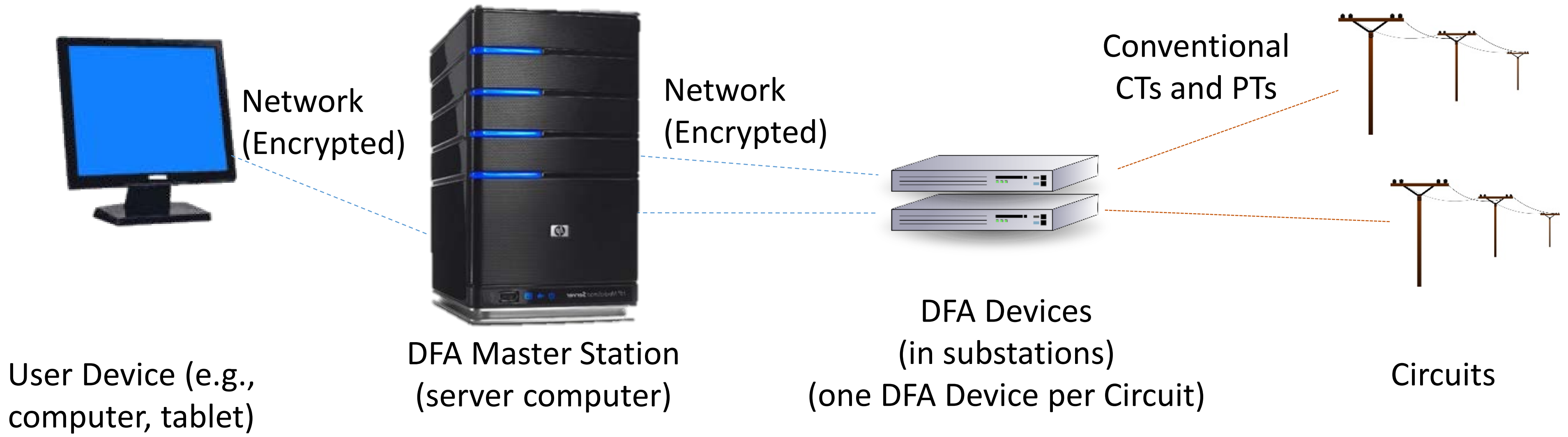
Background
DFA Technology

- Conventional distribution operations have limited awareness of circuit events and conditions.
- DFA technology, developed by Texas A&M Engineering, continuously monitors conventional CTs and PTs, with high fidelity, and applies sophisticated waveform classification software to detect circuit events, including incipient failures. It reports them to personnel for action.
- Improved visibility of circuit events enables improved circuit management and operations.

Background

DFA Monitoring Topology



Each substation-installed DFA Device runs waveform analysis and classification software and then sends results to a central DFA Master Station. Personnel access DFA results via browser connection to the DFA Master Station.

Background
Texas Power Line-Caused Wildfire Mitigation Project

- Because many wildfires result from power line events, the Texas legislature established the Texas Power Line-Caused Wildfire Mitigation project, based on Texas A&M Engineering's DFA technology.
- Participants instrumented 60+ circuits with DFA circuit monitors.

Austin Energy	Bluebonnet Electric Coop
BTU (Bryan Texas Utilities)	Concho Valley Electric Coop
Mid-South Synergy Electric Coop	Pedernales Electric Coop
Sam Houston Electric Coop	United Cooperative Services

- Most DFA circuit monitors have been installed 2-3 years.
- Multiple participants are expanding deployments in 2018.

Background
Texas Power Line-Caused Wildfire Mitigation Project

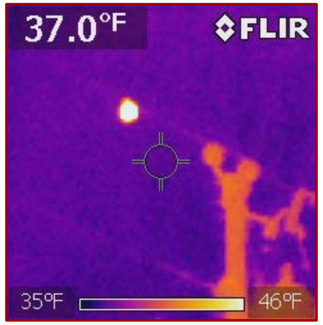
Partial List of Events Detected and Corrected by Project Participants

- Detection and repair of substantial number of routine outages, without customer calls.
- Detection and location of tree branch hanging on line and causing intermittent faults.
- Detection and location of intact tree intermittently pushing conductors together.
- Detection and location of broken insulator that resulted in conductor lying on and heavily charring a wooden crossarm.
- Detection and location of catastrophically failed lightning arrester.
- Detection and location of arc-tracked capacitor fuse barrel.
- Detection and location of multiple problems with capacitor banks.

Most events have potential for fire ignition and also affect reliability and service quality.

Case Study
Concho Valley Electric Cooperative
31-Day Incipient Clamp Failure

The Series Arcing Phenomenon



- Series arcing occurs when a current-carrying device develops a “hot spot” and represents incipient failure of the device.
  - Contacts of clamps, switches, and cutouts (many documented by DFA program).
  - Maybe splices, but these have not been documented by DFA program.
- Whereas conventional faults cause current to flow in <u>unintended</u> paths, series arcing interferes with current flow in an <u>intended</u> path.
- Field experience with DFA demonstrates that series arcing often occurs for hours to weeks before a device fully fails and causes an outage.
- Before final failure, series arcing may cause intermittent, hard-to-diagnose issues, including blown fuses, momentary trip/closes, flickering lights, ...

Case Study
31-Day Series Arcing (Incipient Clamp Failure)

Subject circuit

- 25 kV
- Conventional four-wire overhead
- 268 miles of exposure, 44.9 miles furthest extent
- 427 active meters
- Almost entirely oilfield load
- RF-based AMI across entire system

Failing Switch/Clamp Report from DFA

	[illegible]	[illegible]	Single-phase fault	C	Short-lived fault	N/A	2017-10-25 08:50:11
	[illegible]	[illegible]	Multi-phase trip	BC	F-(1.5c,417A,BCN)-T-(4,6,4)%	1 op	2017-10-24 10:59:58
+	[illegible]	[illegible]	Probable failure of switch or clamp	B	Estimated load beyond switch/clamp: 194 kVA 80% likelihood switch; 20% likelihood clamp	496 transients (31 days)	2017-10-24 10:07:15
	[illegible]	[illegible]	Single-phase fault	C	Short-lived fault (May affect fault current accuracy) (Experimental) Possible Causes: 80% Animal, 15% Arrester F-(15ms,491A,CN)	N/A	2017-10-23 00:52:52

Probable failure of switch or clamp	B	Estimated load beyond switch/clamp: 194 kVA 80% likelihood switch; 20% likelihood clamp	496 transients (31 days)

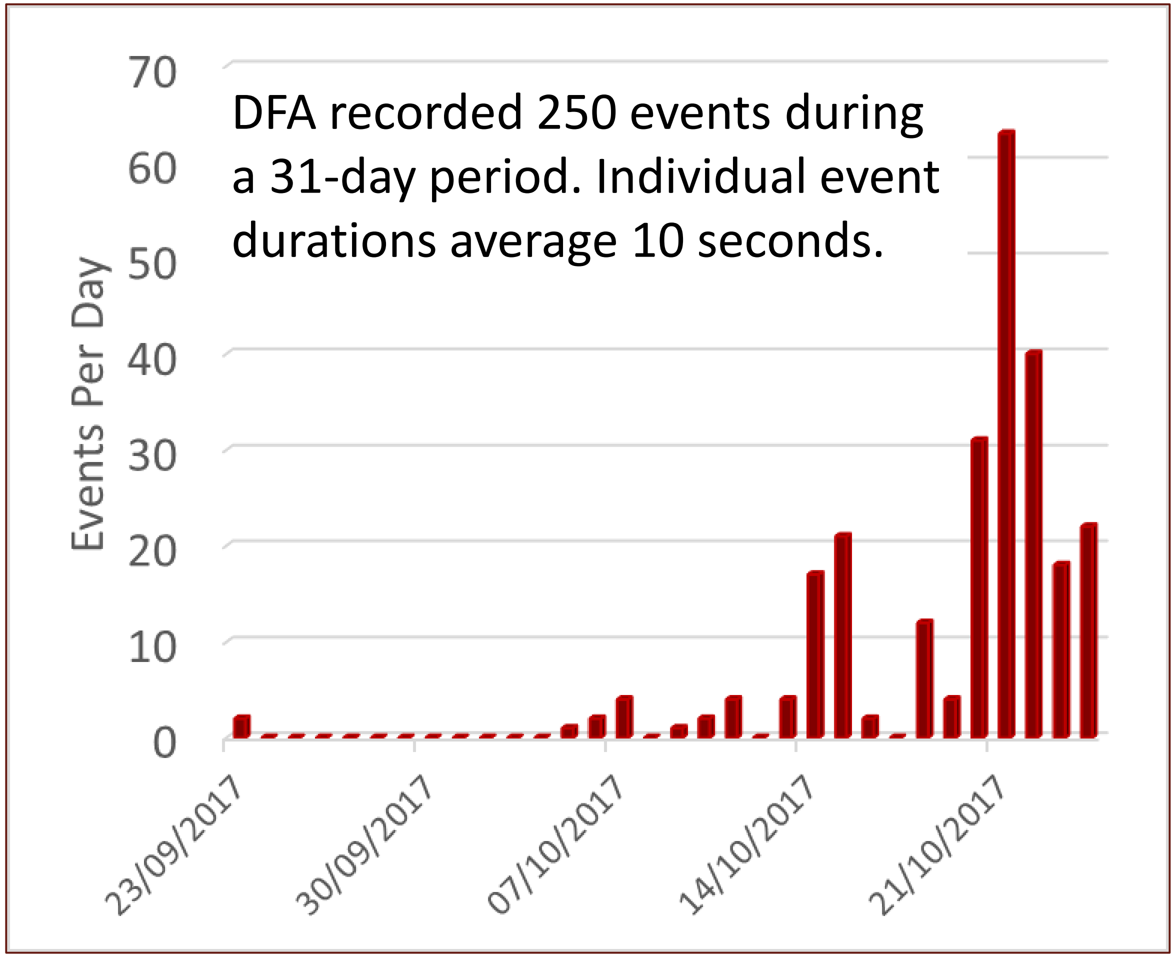
Failing Switch/Clamp Report from DFA

Expand	Substation	Circuit	Event Type	Phases	Comments	Count	Last Occurred
-	[illegible]	[illegible]	Probable failure of switch or clamp	B	Estimated load beyond switch/clamp: 194 kVA 80% likelihood switch; 20% likelihood clamp	496 transients (31 days)	2017-10-24 10:07:15

Export   Show 200 entries   Search:

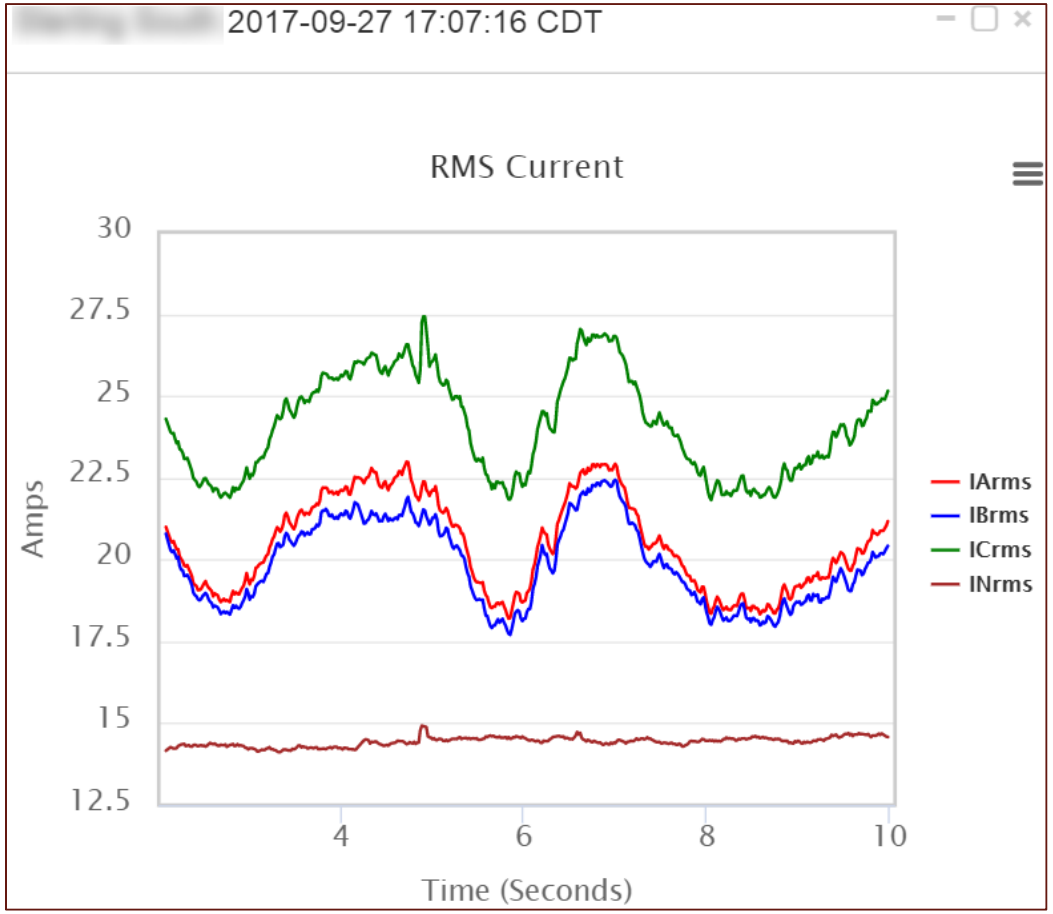
Event Type	Phases	Phase A Amps	Phase B Amps	Phase C Amps	Transients	Last Occurred
Probable failure of switch or clamp(C)	B	14	108	10	1	2017-10-24 10:07:15
Probable failure of switch or clamp(S)	B	10	64	8	6	2017-10-24 09:41:26
Probable failure of switch or clamp(I)	B	9	70	8	3	2017-10-24 09:11:26
Probable failure of switch or clamp(I)	B	5	57	6	2	2017-10-24 06:52:43
Probable failure of switch or clamp(I)	B	8	37	7	1	2017-10-24 06:51:30
Probable failure of switch or clamp(I)	B	8	102	8	1	2017-10-24 06:50:21
Probable failure of switch or clamp(I)	B	7	91	10	2	2017-10-24 06:45:25
Probable failure of switch or clamp(I)	B	8	45	6	1	2017-10-24 06:44:54
Probable failure of switch or clamp(I)	B	7	50	6	1	2017-10-24 06:36:18
Probable failure of switch or clamp(I)	B	10	101	8	1	2017-10-24 06:35:39

Intermittency of Series Arcing



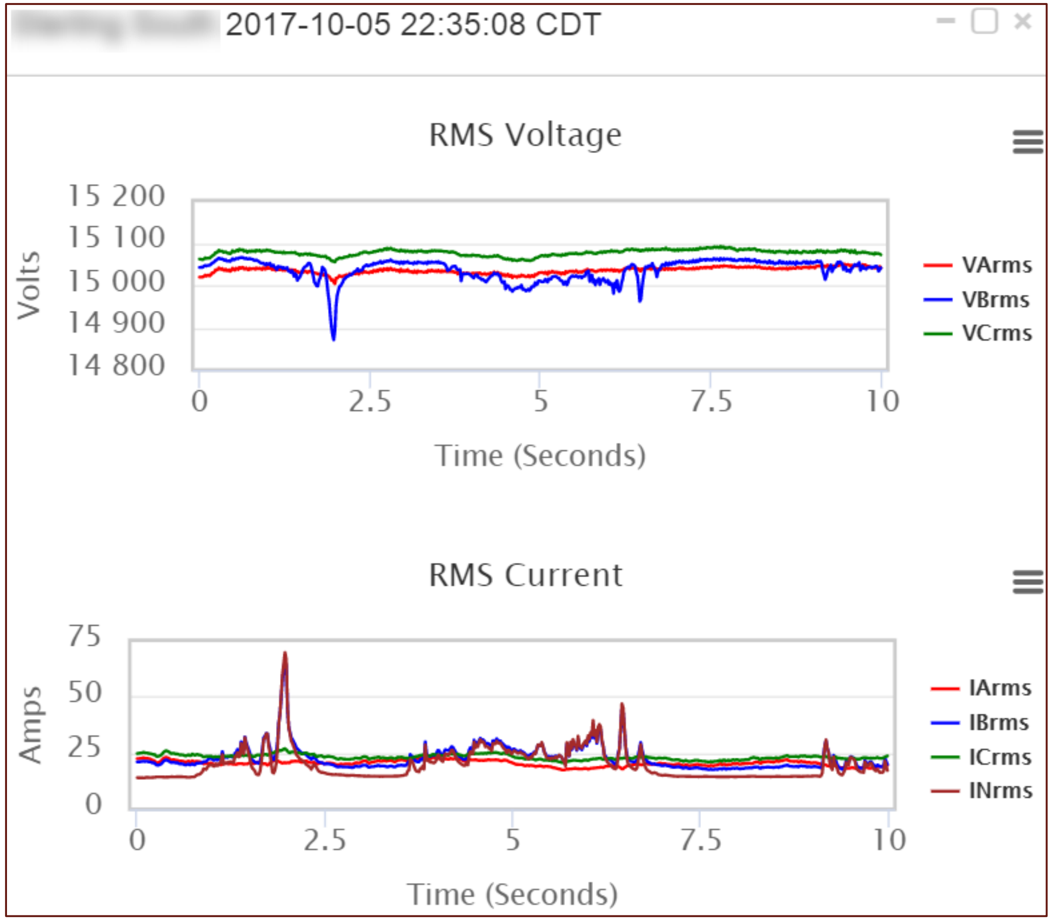
- DFA recorded 250 events in 31 days.
  - 174 were during the final five days.
  - Days 2-12 registered no events.
  - Peak activity was 63 events on day 28.
  - Activity generally increased over time, but not steadily or predictably.
- Most of the total period was quiescent.
  - (250 x 10)/(31 x 24 x 60 x 60) = 0.1%.
  - No activity was recorded 99.9% of time.
- Intermittency makes location with RF, thermal imaging, … difficult.

Subject Circuit – Normal Load



- Graphs come from DFA recordings, which come from conventional circuit CTs and bus PTs at substation.
- Most DFA recordings are 10+ seconds at 256 samples/cycle.
- RMS (one value per cycle) is shown to give “the big picture.”
- Subject circuit is mostly oilfield load.
- Variability shown in this graph is normal for this circuit.

Line Current and Voltage During Series Arcing Event



- Voltage variations are < 1 %.
- Current variations:
  - Peaks of several tens of amperes
  - Highly unstable and intermittent.
  - Magnitudes similar to large loads and inrush events.
- Peaks have sufficient magnitude to trip sensitive overcurrent protection, but limited duration.
- Event signature is subtle.

Challenges of Locating Series Arcing

- For series arcing, current amplitude is largely a function of connected kVA capacity downstream of the failing device, rather than line impedance. Therefore impedance-based fault location methods are ineffective.
- RF and thermal diagnostics might be effective if applied during an active flare-up, but flare-ups occur only a tiny percentage of the time.
- Clamp failures may operate protection in the path upstream or downstream of the failing device. (The “downstream” part is counterintuitive, but it is readily explained by theory and has been documented multiple times by DFA field installations.)

Concho's Search Process and Learnings

- This was Concho's first attempt to locate series arcing.
- Circuit model identified 18 circuit locations that fit DFA parameters.
- Murphy's Law was in full force – clamp was at last location.
- (Murphy cont'd) Conductor burned in two, ending series arcing, right before Concho arrived to check that location. AM radio got a "hit."
- Clamp was on phase B on the source side of a hydraulic E recloser.
  - Bank of three single-phase reclosers, type E, 50A pickup, 2A2B.
  - Since last check, operations counters had incremented by 3 (A), 27 (B), and 2 (C). It is believed that many of the phase-B "counts" resulted from the clamp.
- Concho expected that the AMI system would have data relevant to location of a clamp, but in this case it did not.

The Culprit

Summary and Conclusions

- Concho spent 40 hours searching for this clamp, but learned lessons that should make the process more efficient next time, and considers this a successful first use.
- Sophisticated, automated analysis of high-fidelity data from conventional CTs and PTs can provide improved awareness of circuit events, which can enable better circuit operation.
- When used synergistically with circuit models, AMI, etc., some events are readily located (e.g., most recurrent faults, fault-induced conductor slap); others are more challenging.
- The first use of a new technology or process often is difficult, but lessons can be learned and processes improved.

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