Application of DFA Technology for Improved Reliability and Operations

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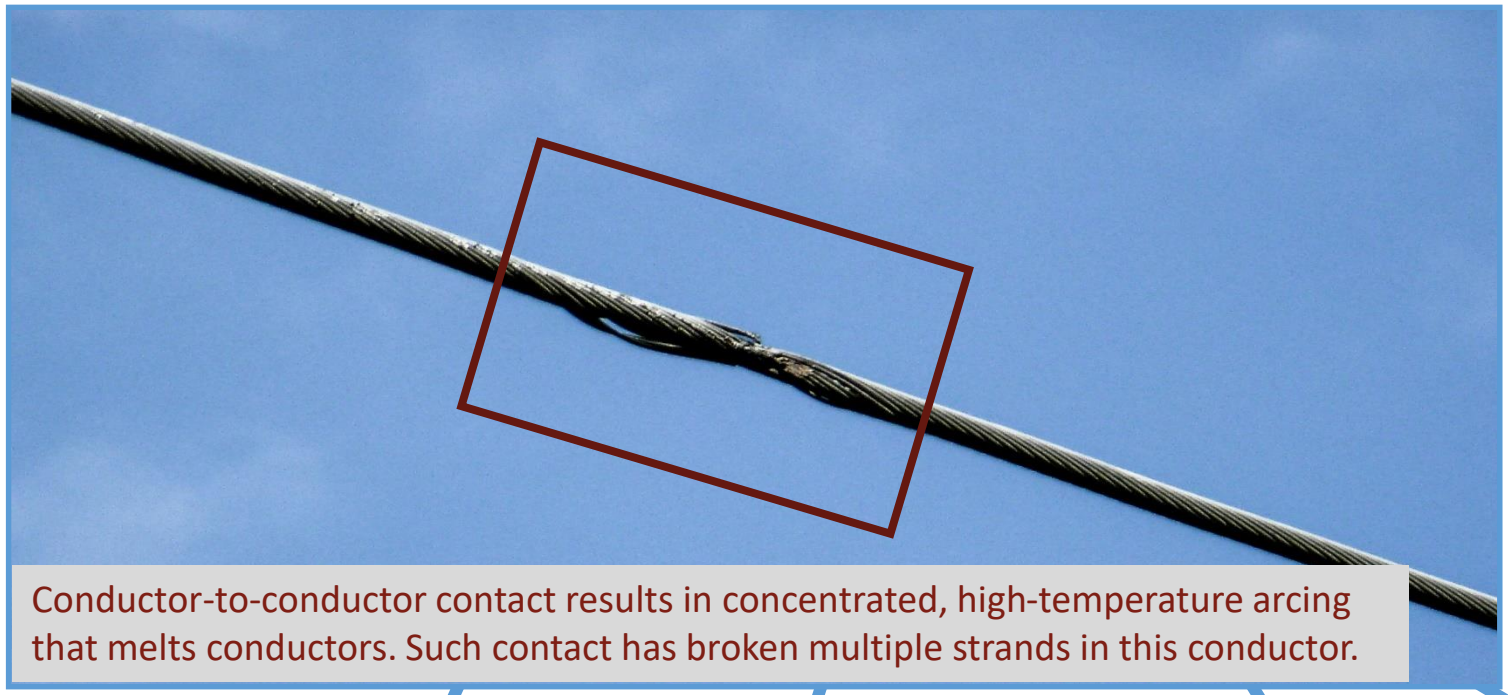
Presentation Overview

- Distribution operations – current practice and limitations
- Distribution Fault Anticipation (DFA) technology
- Texas Power Line-Caused Wildfire Mitigation project
- Pedernales experience with DFA technology
- Pedernales future deployment plans



Conductor-to-conductor contact results in concentrated, high-temperature arcing that melts conductors. Such contact has broken multiple strands in this conductor.

Condition: Fault Induced Conductor Slap (FICS)

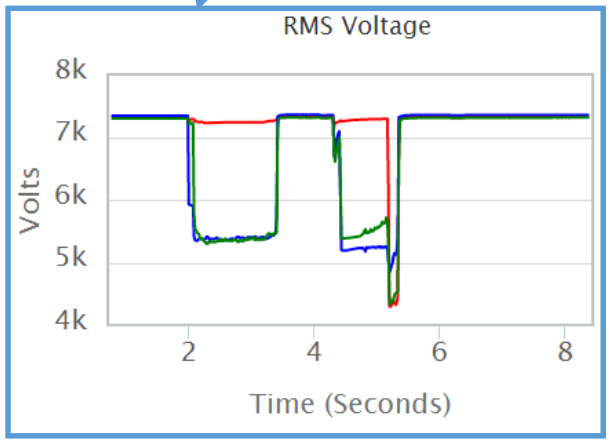
- Utility rarely knows it is happening.
- It is seldom diagnosed or fixed.

Why Does It Matter?

- Dissatisfied customers.
- Repeated power quality problems.
- Repeated outages.
- Progressive damage, leading to more severe problems, including downed conductors.
- With DFA: Fully diagnosable and fixable.

Dissatisfied Customers

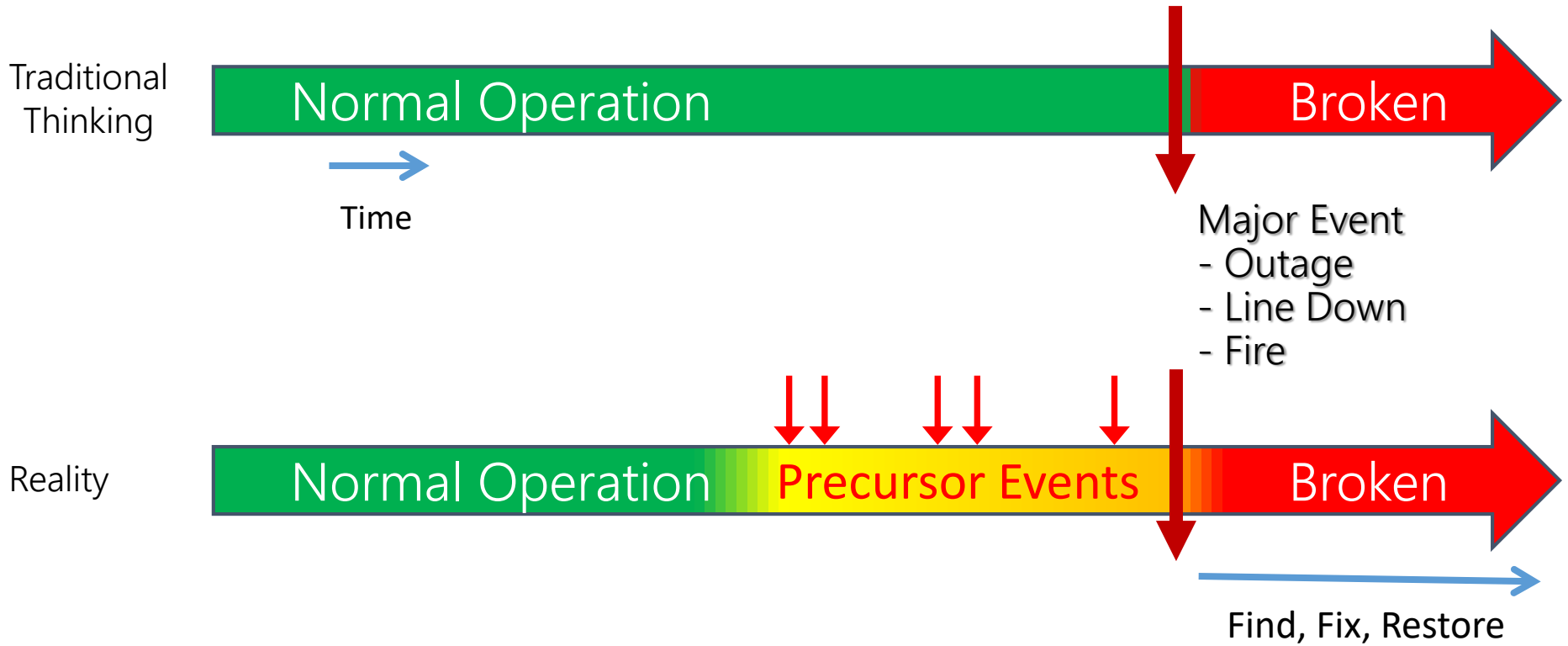
PQ Problems



Outages

Downed Conductors

Distribution Circuit Operating Paradigms



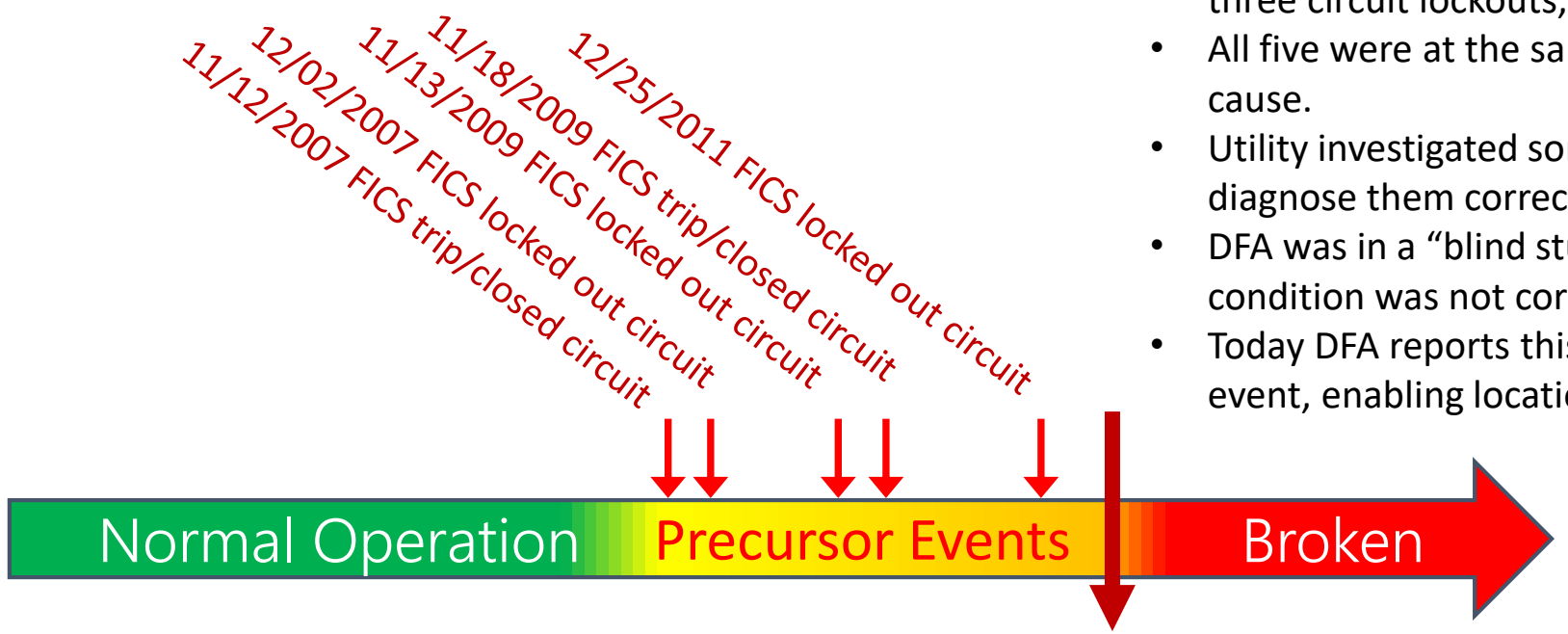
Conventional response starts after outage or other consequential event.

Smart grid response still starts after outage or other consequential event.

Key to better circuit management is awareness of actual circuit activity.

Distribution Circuit Operating Paradigms

Actual Example

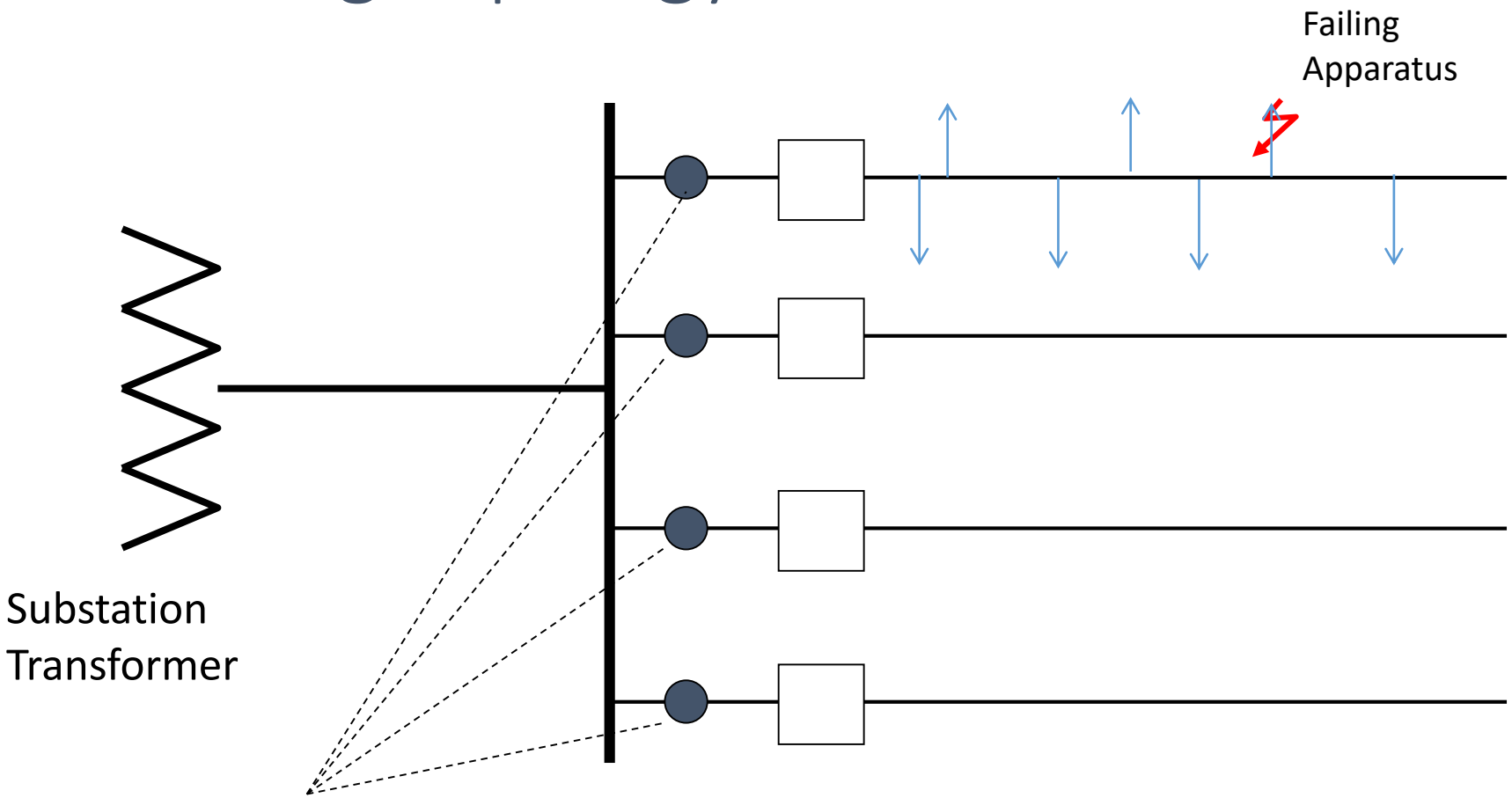


- Five FICS events caused two trip/close operations and three circuit lockouts, over a period of four years.
- All five were at the same location and had the same cause.
- Utility investigated some of the events but did not diagnose them correctly with conventional approaches.
- DFA was in a “blind study” mode during first events, so condition was not corrected.
- Today DFA reports this specific condition, after first event, enabling location and repair.

Repetitive FICS at the same location causes cumulative damage and eventually breaks conductors, causing safety hazards, in addition to power quality and reliability problems.

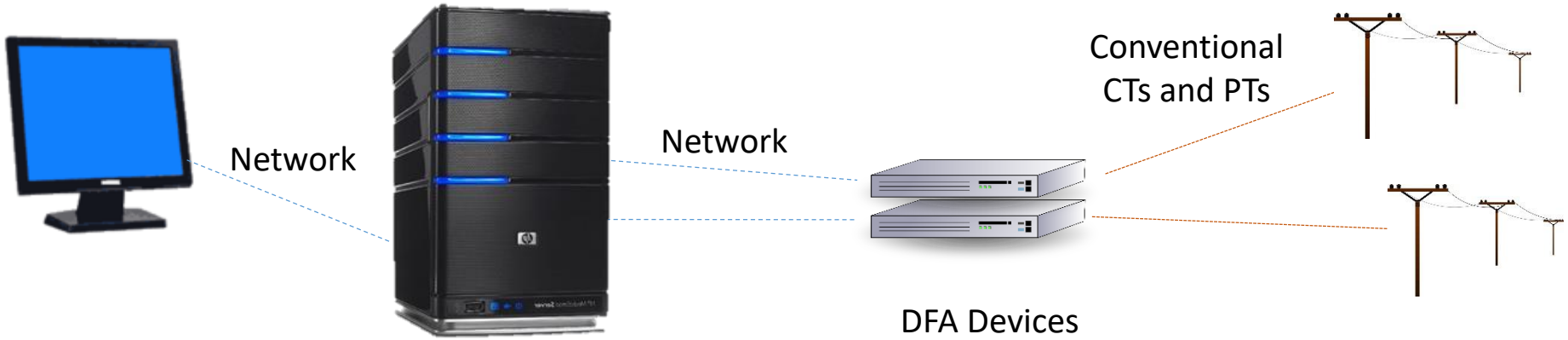
Distribution Fault Anticipation (DFA) Technology

DFA Monitoring Topology



High-fidelity DFA devices connect to conventional CTs and PTs, one per distribution circuit.
Each DFA device is a single, 19” rack-mount device, with connections similar to those of a relay.

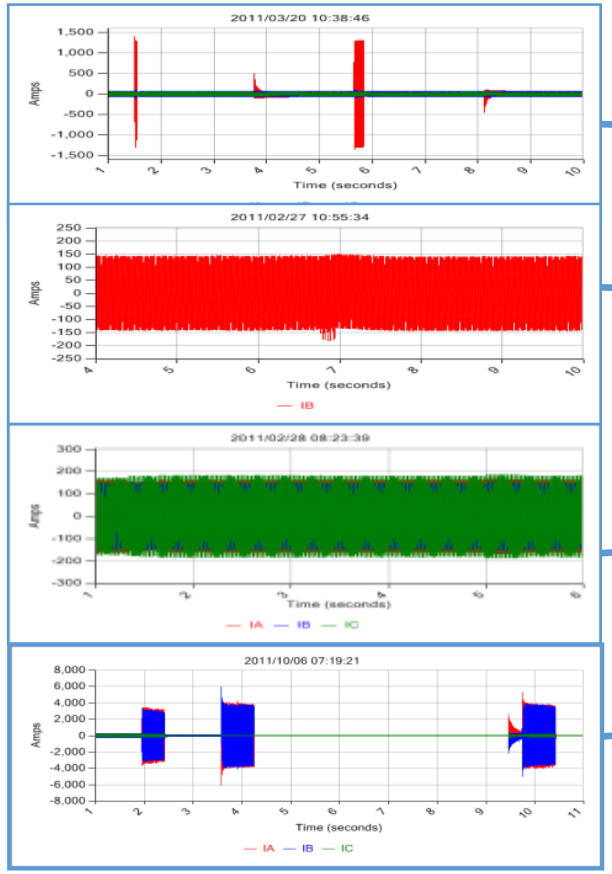
DFA Monitoring Topology



Note: On-Line Waveform Classification Engine software performs waveform analysis in each DFA Device. Results are sent to the DFA Master Station for access by personnel.

Waveform Classification – Behind the Scenes

Inputs: Substation CT and PT Waveforms



Waveform Analytics

DFA On-Line Waveform Classification Engine

(Signal Processing Performed by DFA Device in Substation)

Outputs: Event Reports

Event #1: Temporary fault cleared by trip/close of line recloser

Event #2: Failing hot-line clamp

Event #3: Faulty 1200 kVAR line capacitor

Event #4: Breaker lockout, caused by fault-induced conductor slap

*Analytics applied to high-fidelity substation waveforms report on hydraulic line reclosers, switched line capacitors, apparatus failures, etc, without requiring communications to line devices.

Waveform Classification – Behind the Scenes

DFA On-Line Waveform Classification Engine

(Signal Processing Performed by DFA Device in Substation)

DFA Device software technologies

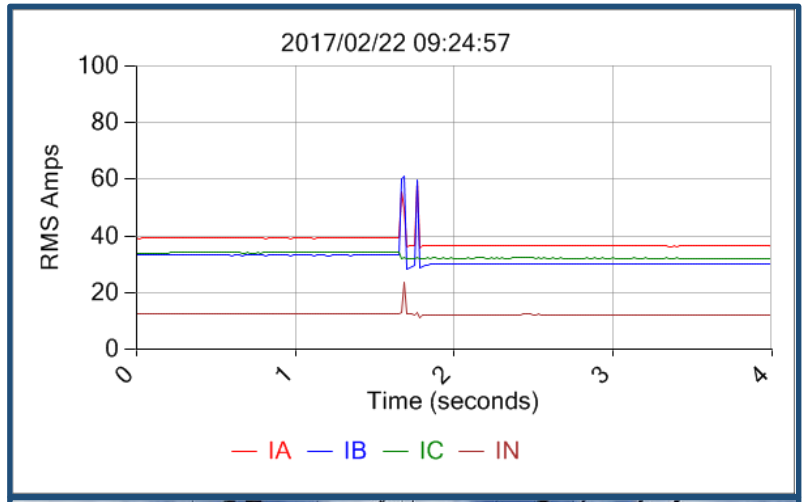
- Multi-rate polyphase filter banks for phase drift compensation
- Fuzzy expert system for classification
- Fuzzy dynamic time warping for shape recognition
- Hierarchical agglomerative clustering for recurrent faults
- Finite state machine for fault SOE identification
- Shape-based and event-specific feature extraction
- Hierarchical classification architecture for feature space dimensionality reduction

The DFA on-line waveform classification engine uses sophisticated software to analyze waveforms and thereby characterize circuit events.

Use Case Summary

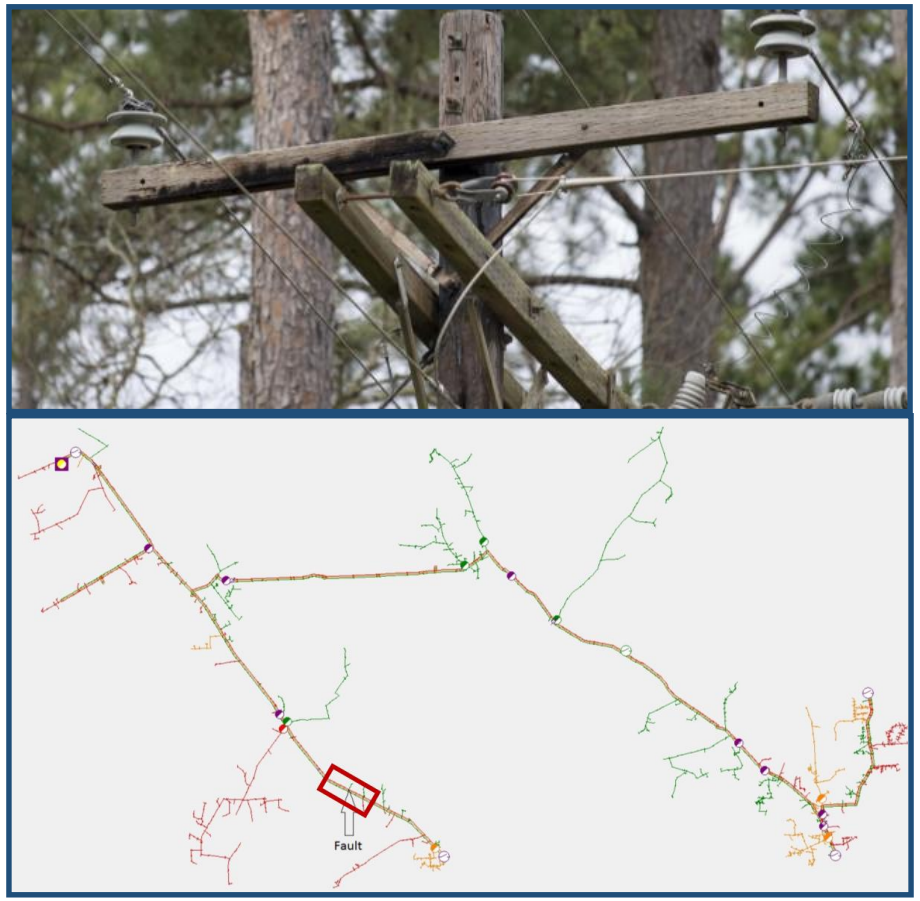
Partial Loss of Vacuum in Capacitor Switch

- This utility controls line capacitors via radio and monitors kvars to confirm switching.
- DFA reported ‘severe restrike’ during switching 17 February 2017 and again five days later.
- The utility had no other indication of a problem.
- Utility used radio dispatch to determine the offending bank and then dispatched a crew.
- The bank’s suspect vacuum switch was tested and determined to have lost partial vacuum.
- The vacuum switch was replaced prior to failure, thus avoiding PQ problems and potential escalation of the problem to a full vacuum failure.



Crossarm Charred by Displaced Phase Conductor

- The subject circuit has 109 miles of exposure.
- During a routine review of DFA records, the utility noted two similar faults, one day apart.
- Putting DFA fault current into model-based fault location software identified two possible locations, on two major branches.
- The major branches have electronic reclosers. One had “seen” the faults; the other had not.
- The problem was six spans from the prediction.
- Because of a broken insulator, a phase conductor was lying on and charring a wooden crossarm.



DFA Technology - Summary

- Conventional distribution operations have limited visibility (or awareness) of circuit events and conditions.
- DFA technology improves visibility (or awareness) of circuit events by applying a sophisticated on-line waveform classification engine to high-fidelity waveforms from CTs and PTs.
- Improved visibility enables improved circuit management and operations.

Texas Power Line-Caused Wildfire Mitigation Project

How Do Power Lines Cause Fires?


Downed Conductors


Clashing Conductors


Vegetation


Failing Apparatus

Texas Power Line-Caused Wildfire Mitigation Project

- Recognizing that many wildfires result from power line events, the Texas legislature is supporting the Texas Power Line-Caused Wildfire Mitigation project, based on Texas A&M Engineering's DFA technology.
- Current Participants

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

- Most DFA circuit monitors have been installed 12-15 months.

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 member 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 heavily charring a wooden crossarm.
- Detection and location of catastrophically failed lightning arrester.
- Detection and location of arc-tracked capacitor fuse barrel.

These event have potential for fire ignition and also affect reliability and service quality.

Pedernales DFA Experiences and Future Plans

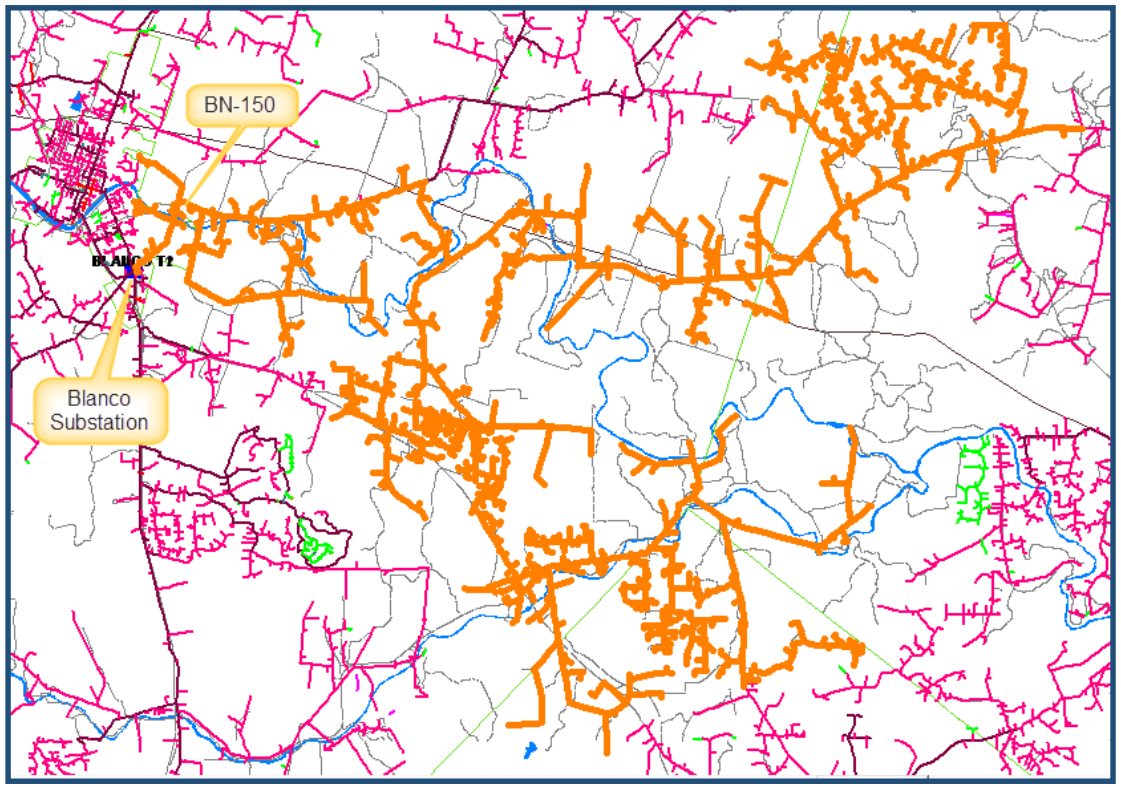
Pedernales Facts and Figures

- Largest distribution cooperative in the United States
- 8,100 square-mile service territory, west of Austin, Texas
- 290,654 meters
- Adding 1,300+ meters/month
- 21,800 miles of distribution (12.5kV, 25kV)
- 304 miles of transmission

- Pedernales instrumented ten circuits with DFA in early 2016.

Recurrent Fault Reported by DFA

- BN-150
- Serves area east of Blanco, Texas (orange lines on circuit map)
- 1008 Meters
- 153 miles of primary conductor
- 7.2/12.5 kV
- DFA installed December 10, 2015



Recurrent Fault Reported by DFA

- March 6, 2016, DFA reported a recurrent fault on BN-150

Single-phase reclose	C	F-(9.5c,301A,CN,-85°)-T-(0,0,14)%-1.5s-C	1 op	2016-03-06 08:57:25
Fault	C	F-(85.0c,302A,CN,67°)	N/A	2016-03-06 01:30:57
Recurrent fault	C	Single-Phase reclose, 299 Amps	2 (35 minutes)	2016-03-06 01:30:47
Single-phase reclose	C	F-(9.0c,303A,CN,50°)-T-(0,0,17)%-1.4s-C	1 op	2016-03-06 01:30:47
Single-phase reclose	C	F-(10.0c,295A,CN,113°)-T-(0,0,15)%-1.4s-C	N/A	2016-03-06 00:55:33

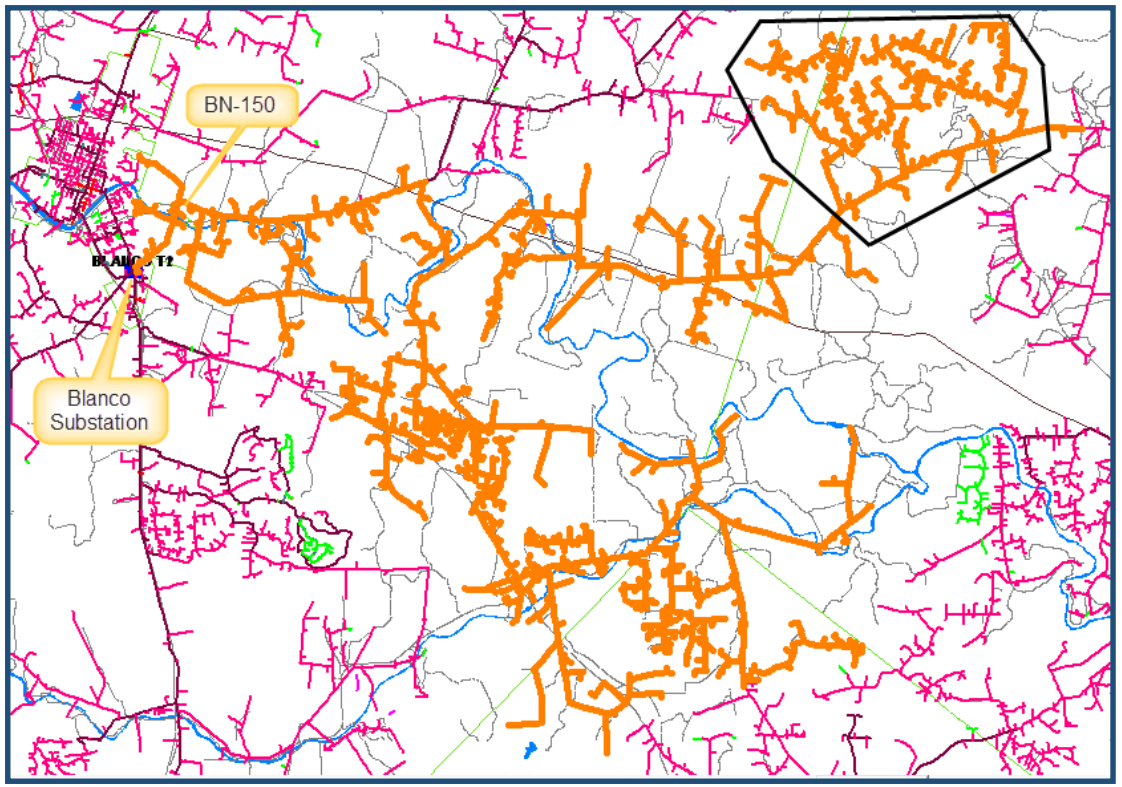
- SCADA system recorded the following:

#	DATE	TIME	EVENT	LOCATION	CURRENT
1	03/06/16	08:57:14.704	CG	14.41	336
2	03/06/16	01:30:47.129	CG	14.99	322
3	03/06/16	01:30:46.704	CG	14.81	319
4	03/06/16	01:30:46.046	CG	14.91	320
5	03/06/16	01:30:36.418	CG	15.03	320
6	03/06/16	00:55:22.518	CG	15.21	317

Recurrent Fault Reported by DFA

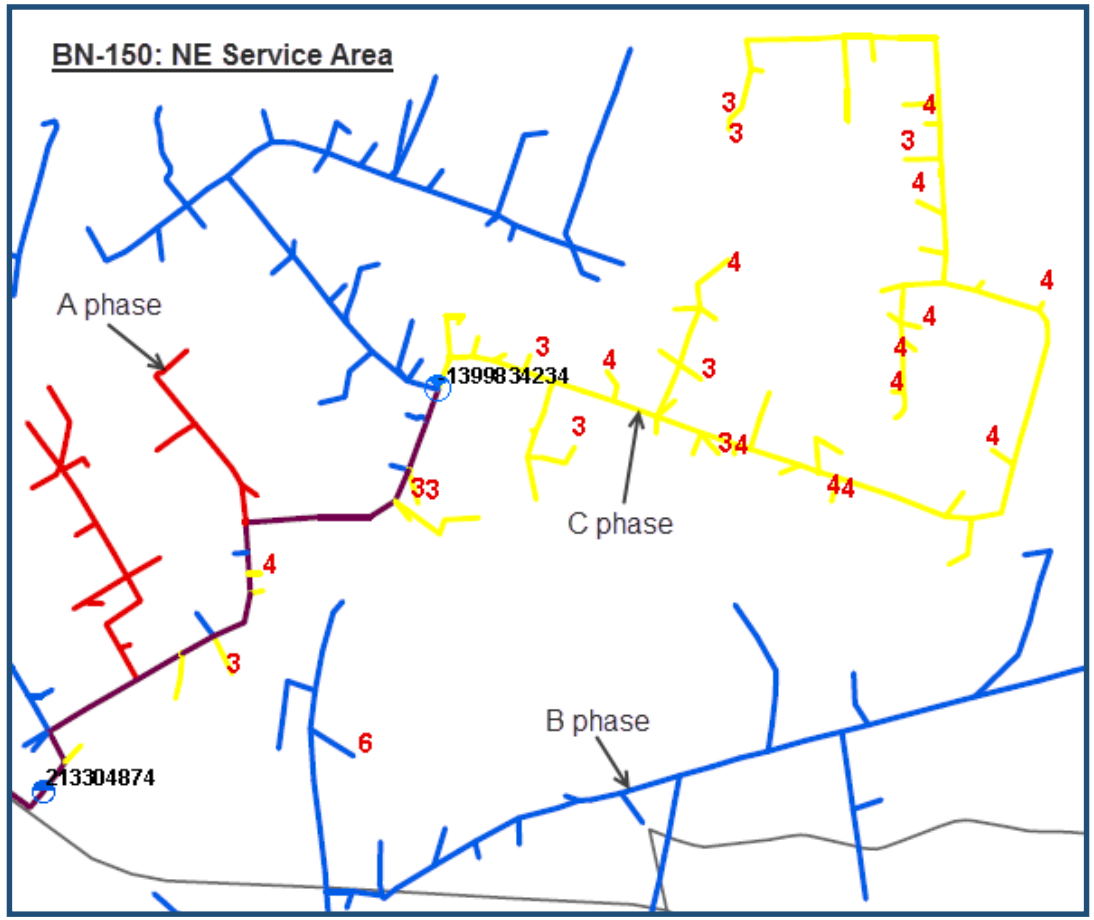
What did we know?

- No outage and no complaints of blinks
- Phase to ground fault on C phase
- Six events over nine-hour period
- 300 amps
- Behind single phase recloser that dropped about 15% of feeder load.
- Combining this information suggested the region outlined on the circuit map.



Recurrent Fault Reported by DFA

- DFA information provided actionable notice that a problem existed.
- Blink count confirmed which recloser was operating, consistent with information provided by DFA.
- A targeted patrol identified the source of the problem as a branch on the line.



Recurrent Fault Reported by DFA

Results with DFA:

- Located and easily resolved the problem (branch on line)
- No damage to conductor
- Rural area
- Averted fire hazard
- Minimized crew time
- As a side benefit - corrected phasing on map

Absent DFA:

- Likely would not have known about the problem
- Would have had a wildfire hazard

Forensic Use of DFA to Diagnose Fault

BN150	Blanco	Breaker trip	A	2.0s-C-F-(183.0c,536A,AN,29°)-T-2.1s-C-F-(144.5c,555A,AN,-158°)-T-10.4s-C-F-(133.0c,590A,AN,-158°)-T	3	2016-02-23 01:49:22

- Fault events, 2/23/2016, BN-150.
- Initially reported to be lightning.
- The cause was a buzzard nest between the center and outside phase.
- The fault occurred several times, increasing each time before it tripped the breaker.
- Center phase conductor (A phase, 795 AAC) was damaged.
- Conductor broke at the insulator and fell to the ground on both sides of the pole.

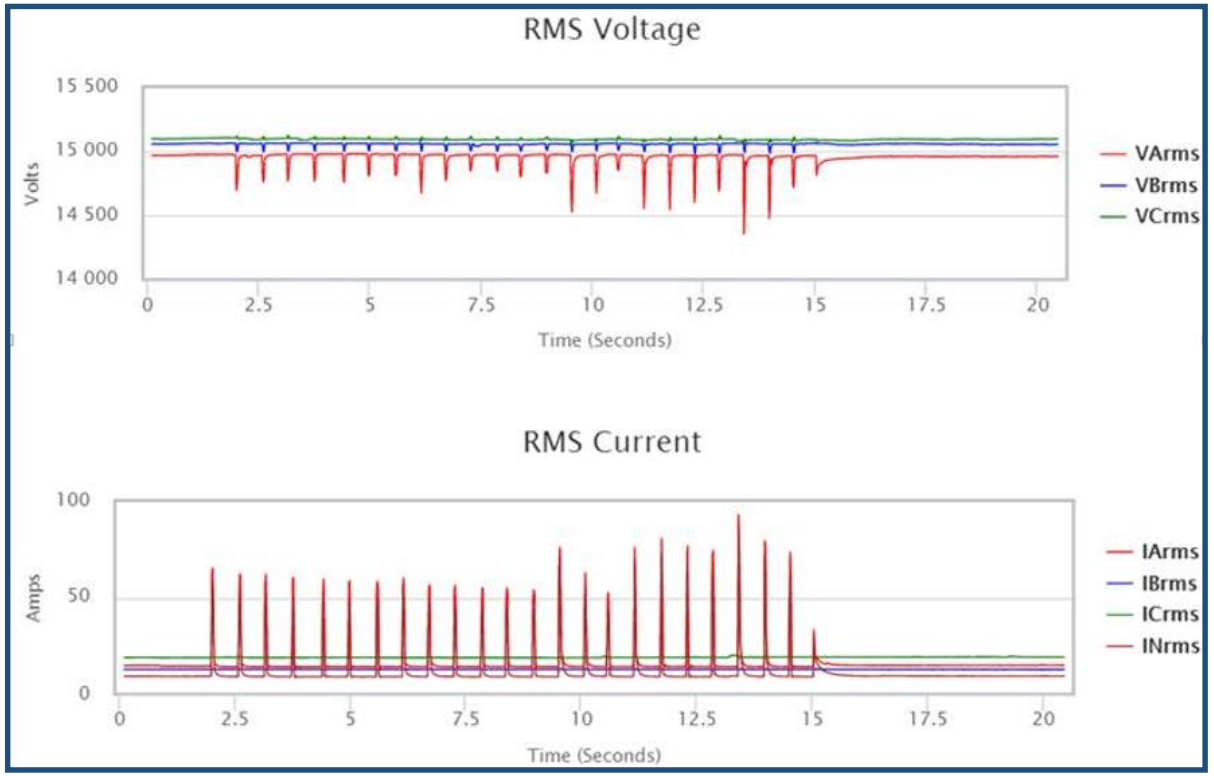
Failed Vacuum Bottle on Capacitor Bank

- DS-160, 7/8/2016.
- DFA reported capacitor with phase A not functioning.
- Investigation confirmed failed vacuum bottle on phase A.

DS160	Dripping Springs	Capacitor on (unbalanced)	BCN	Yes	2016-07-08 14:27:23	TWACS
DS160	Dripping Springs	Capacitor on (unbalanced)	BCN	Yes	2016-07-07 14:21:57	None
DS160	Dripping Springs	Capacitor on (unbalanced)	BCN	Yes	2016-07-06 14:25:41	TWACS
DS160	Dripping Springs	Capacitor on (unbalanced)	BCN	Yes	2016-07-05 14:11:15	TWACS
DS160	Dripping Springs	Capacitor on (unbalanced)	BCN	Yes	2016-07-04 14:22:44	None
DS160	Dripping Springs	Capacitor on (unbalanced)	BCN	Yes	2016-07-03 14:58:18	TWACS
DS160	Dripping Springs	Capacitor on (unbalanced)	BCN	Yes	2016-07-02 14:56:47	None
DS160	Dripping Springs	Capacitor on (unbalanced)	BCN	Yes	2016-07-01 14:40:21	TWACS

Anomalous Event

- RS-40, 10/6/16
- Anomalous A-Gnd event
- 23 current pulses over a 13-second period.
- About 60 to nearly 100 amps.
- Too large for an individual load, even a motor start.
- Very consistent in both duration and separation – something mechanical.
- Possibilities:
  - Some kind of large load (oil field)
  - Burned out load controller
  - Burned out recloser
  - Burned out remote controlled switch
- Patrolled, interviewed, monitored
  - Has not repeated
  - Not able to identify any possible cause



Pedernales – Use Summary and Future Plans

- Pedernales has had DFA on ten circuits since early 2016.
- DFA has provided the sole actionable information for multiple problems and has provided a tool for forensic analysis of events.
- Pedernales plans to deploy DFA system wide:
  - More than 200 circuits
  - Deployment planned over three-year period

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