Operational Experience with DFA Technology at Bluebonnet Electric Cooperative and Mid-South Synergy

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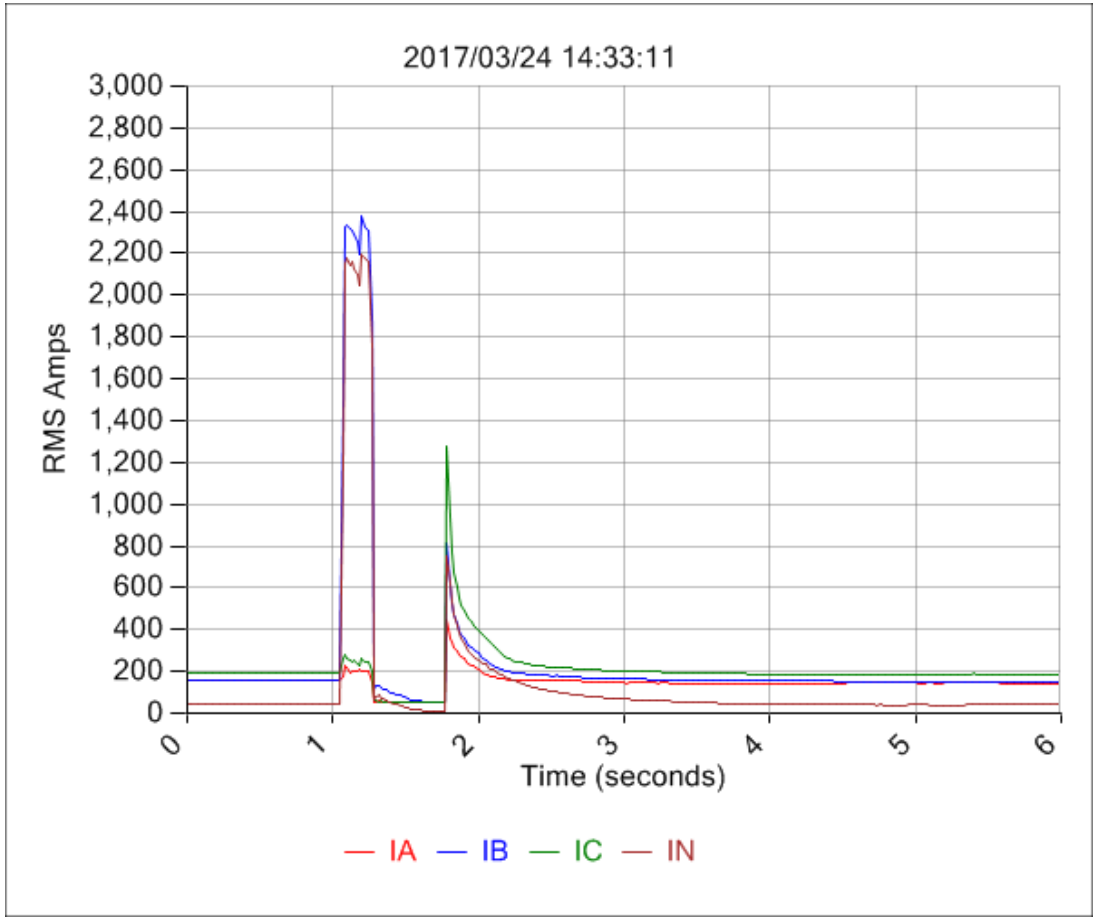
Kim Bender
Sr. Control Center Operator
kim.bender@bluebonnet.coop
979-203-9165
Bluebonnet Electric Coop

Dr. Comfort Manyame
Sr. Manager – Research &Technical Strategy
cmanyame@midsouthsynergy.com
936-825-5103
Mid-South Synergy Electric Coop

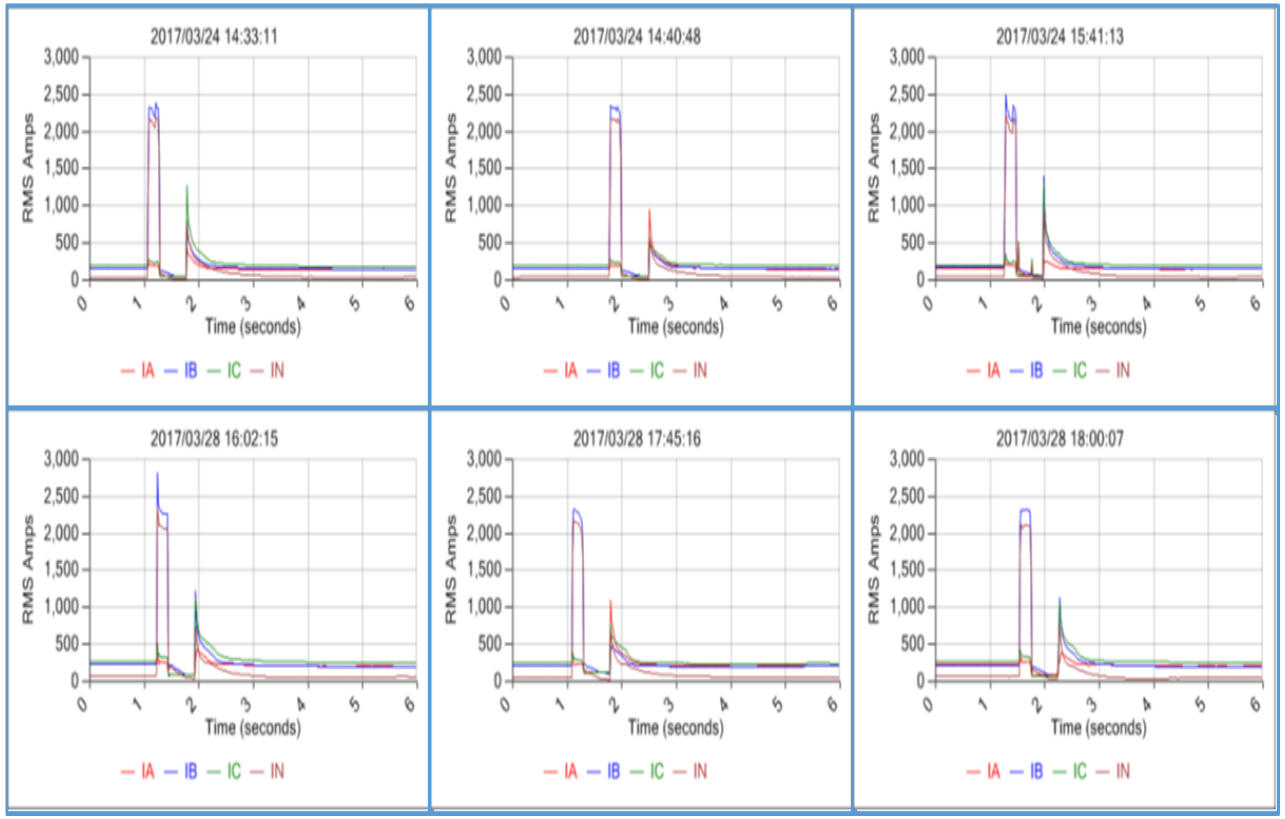
Carl L. Benner, P.E.
Research Associate Professor
carl.benner@tamu.edu
979-676-0499
Texas A&M Engineering

What Would You Do?

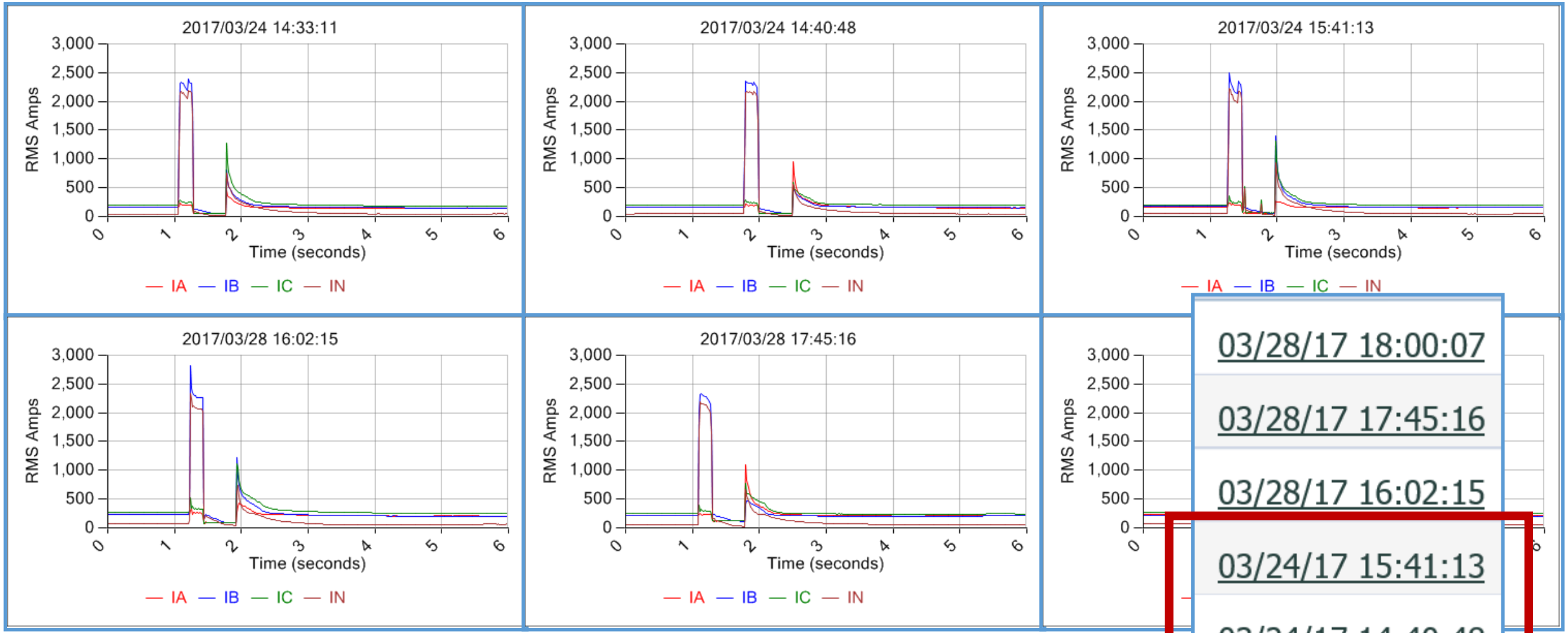


- Assume you know this fault occurred during a storm.
  - Downstream recloser trip/closed
  - No substation breaker operation
  - No outage
- What is the significance of this event?
- What would you do in response?

What Would You Do?



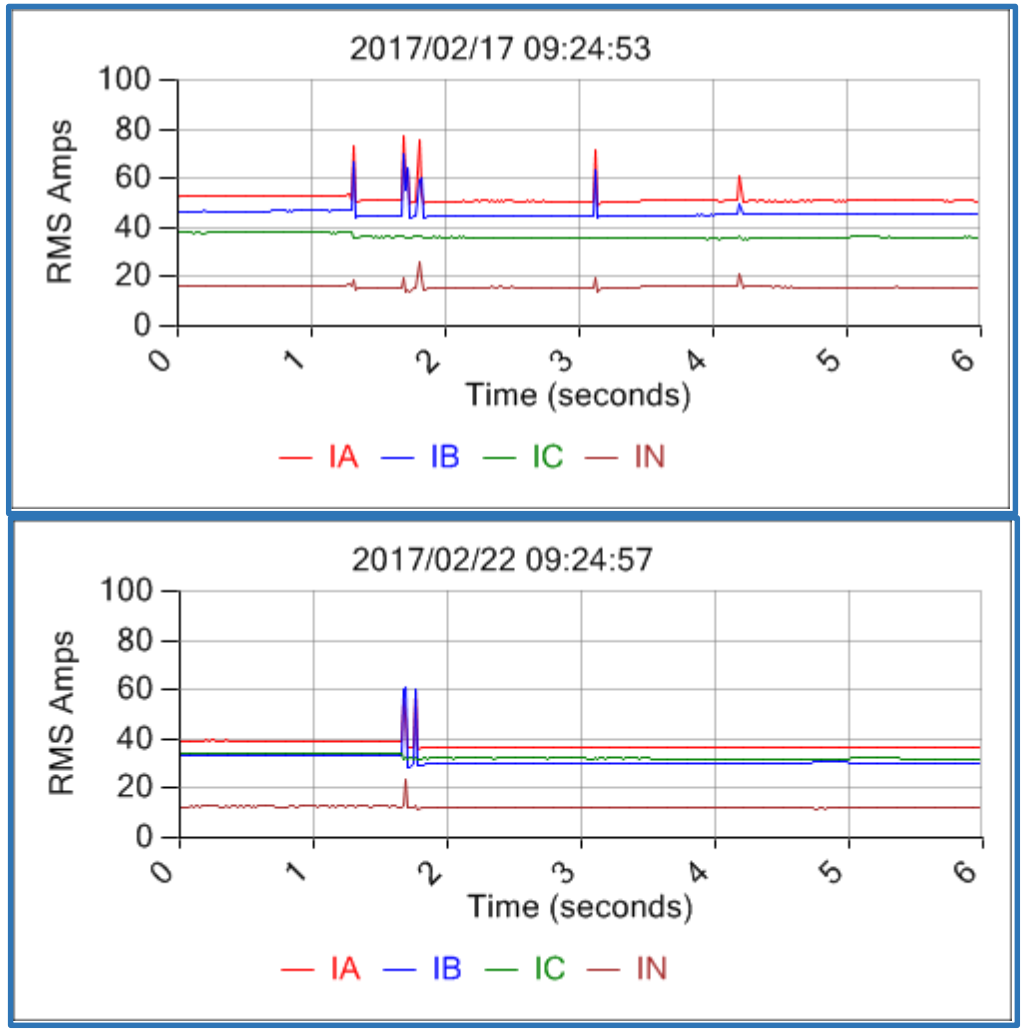
- Now assume you know that six <u>identical</u> faults have occurred in four days.
  - Downstream recloser trip/closed
  - Still no outage
- Now what is the significance of the events?
- Now what would you do in response?



Possible recurrent fault	B	Three-Phase reclose, 2332 Amps	6 (4 days)

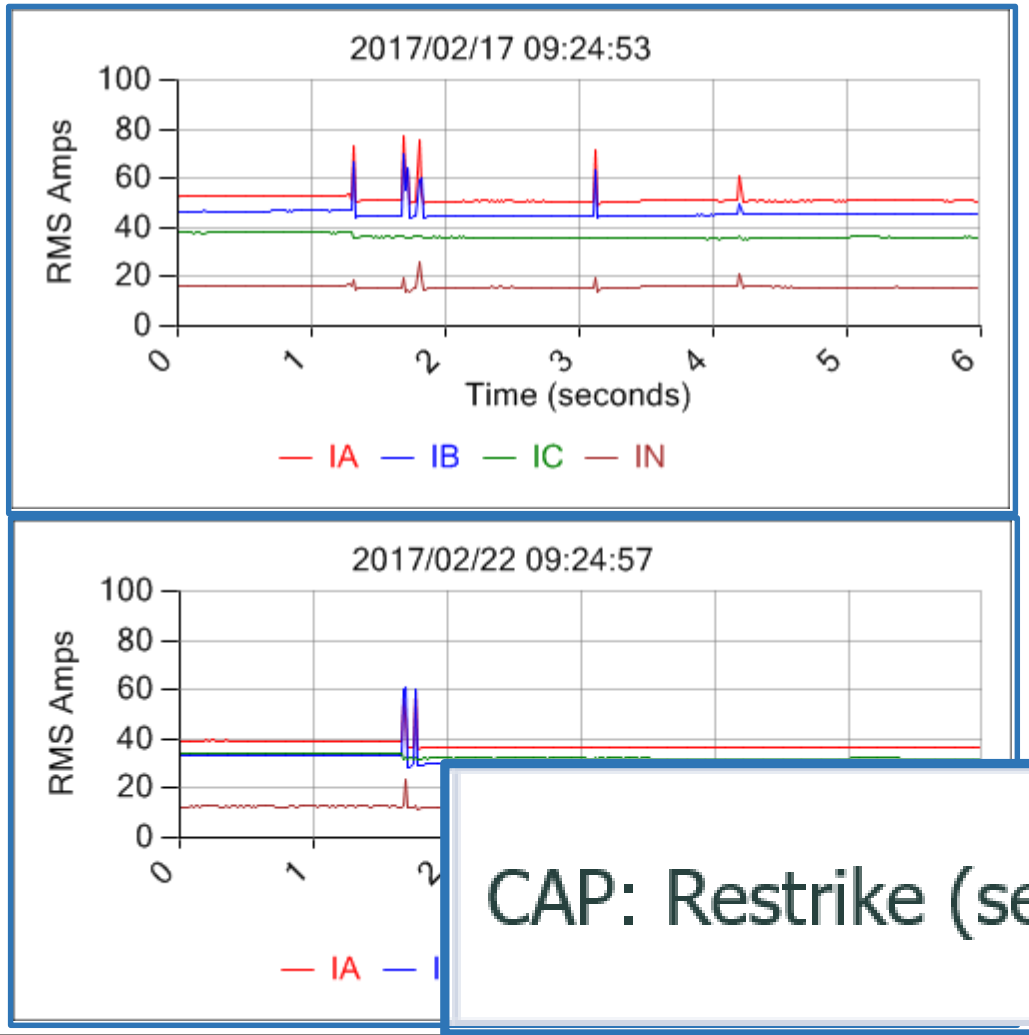
03/28/17 18:00:07
03/28/17 17:45:16
03/28/17 16:02:15
03/24/17 15:41:13
03/24/17 14:40:48
03/24/17 14:33:11

Another “What Would You Do?”



- Assume these events are happening on one of your circuits.
- You probably have no way to know they are occurring.
- Even if you did know they were occurring, what do they mean, and what would you do?

Another “What Would You Do?”



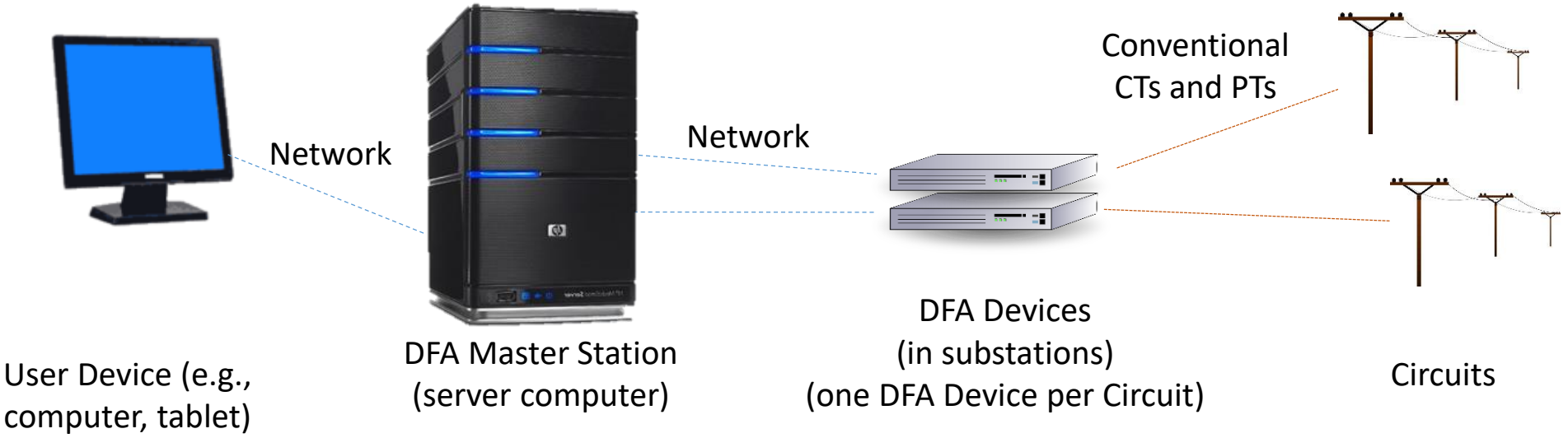
- Now assume that you do know of the events and that you know they are severe restrikes in a switch on a 600 kvar switched capacitor.
- Now what is the significance of the events?
- Now what would you do in response?

CAP: Restrike (severe)	B	191	194	190	02/22/17 09:24:57

The Point

- You can respond differently when you have better awareness.
- Both of the preceding events were reported by the DFA system and were actionable. The key was knowing of their existence.
- This presentation provides a brief overview of DFA technology, developed by Texas A&M Engineering, along with selected examples of how Bluebonnet and Mid-South Synergy are using it to improve operations.
  - Bluebonnet has had 14 circuits fitted with DFA for about 18 months.
  - Mid-South Synergy has had 10 circuits fitted for a similar period.
  - Both anticipate adding DFA to more circuits in 2018.

DFA Technology Monitoring Topology



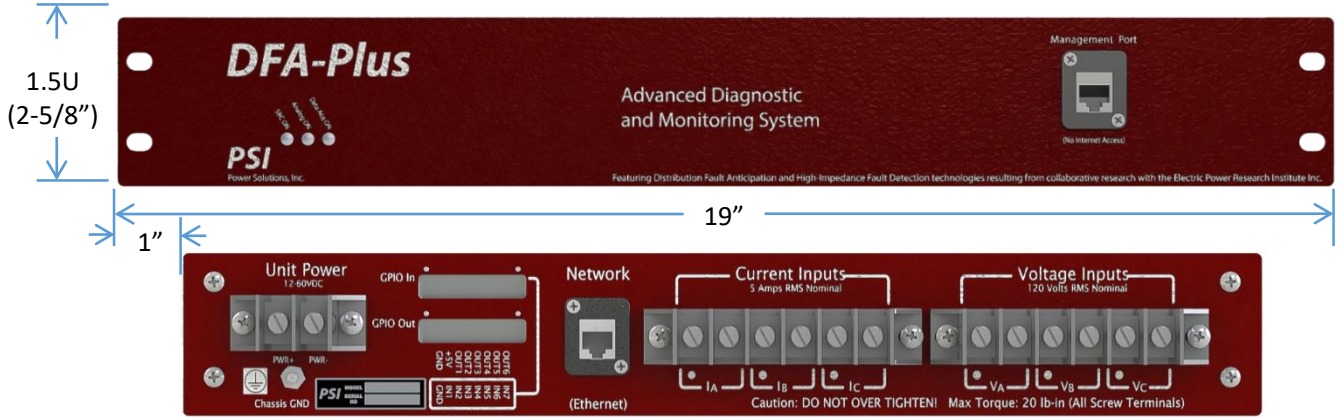
Each DFA device runs On-Line Waveform Classification Engine software that analyzes waveforms to infer circuit events. Results are sent to the DFA Master Station for access by personnel.

DFA Technology Hardware Device Photos

DFA Device Drawings - August 2015. Subject to change.

<u>Rack-Mount DFA-Plus Device</u>
Case depth is 11-3/16”. Current, voltage, and unit power terminals on rear add 1” for total depth of 12-3/16”.
Connections to rear of each Device:
* Unit power, battery-backed, 12-60VDC
* (3) Current inputs, 5AAC nominal
* (3) Voltage inputs, 120VAC nominal
* Ethernet/Internet, RJ45 twisted-pair (Network port)

User is responsible for providing unit power, Internet service, CTs, PTs, and all cabling.
The Management Port on the front of the Device is for setup and diagnostic purposes only and is not intended to be connected during normal operation.



Hardware platform by Power Solutions LLC.

DFA Technology - Summary

- DFA technology continuously monitors CT and PT waveforms and infers circuit events by applying sophisticated signal processing software (on-line waveform classification engine) to those waveforms.
- This improves situational awareness and provides actionable information.

Texas Power Line-Caused Wildfire Mitigation Project

- Because many wildfires result from power line events, the Texas legislature has supported the Texas Power Line-Caused Wildfire Mitigation project, based on Texas A&M Engineering's DFA technology.
- Eight utility companies have participated in the project by installing DFA on their circuits and working collaboratively with Texas A&M.
- Partial List of Events Detected and Corrected by Project Participants
  - 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 wooden crossarm (to be detailed later in this presentation).
  - Detection and location of catastrophically failed lightning arrester.
  - Detection and location of arc-tracked capacitor fuse barrel.
  - Detection and location of multiple capacitor bank problems.
- Multiple participants are planning expanded deployments in 2018.

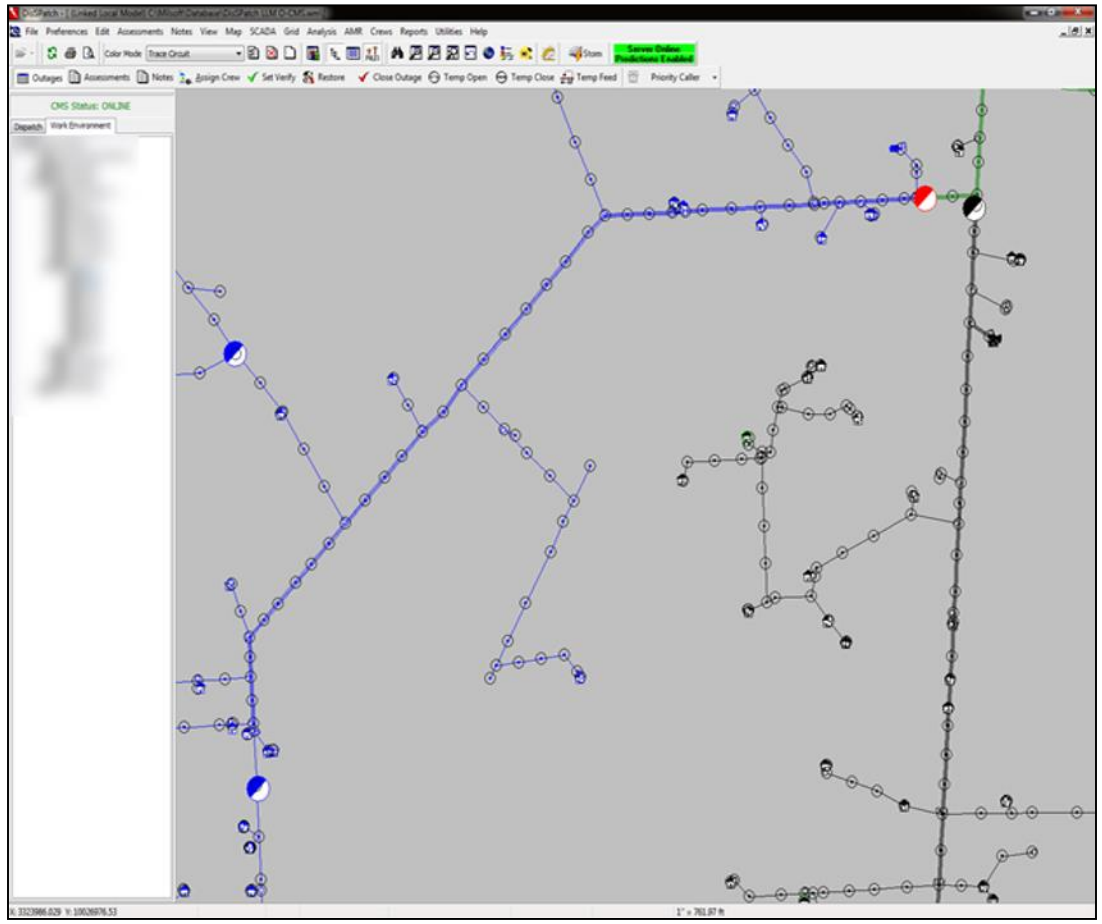
Bluebonnet Electric Cooperative's Use of DFA Technology

Recent Use of DFA at Bluebonnet

- Bluebonnet operators use multiple tools to manage circuit operations.
  - A small percentage of line reclosers are monitored and can provide fault currents.
  - Milsoft-based circuit model includes device locations and can predict possible fault locations based on measured fault current levels.
  - TWACS-based meters can be pinged to confirm outage locations.
- DFA provides another tool to aid in problem identification and location.
- DFA presents “plain English” reports via secure login to a website.
- The following case studies provide high-level synopses of several cases where Bluebonnet has used DFA to improve response to faults, outages, and other problems.

Bluebonnet Use Case #1

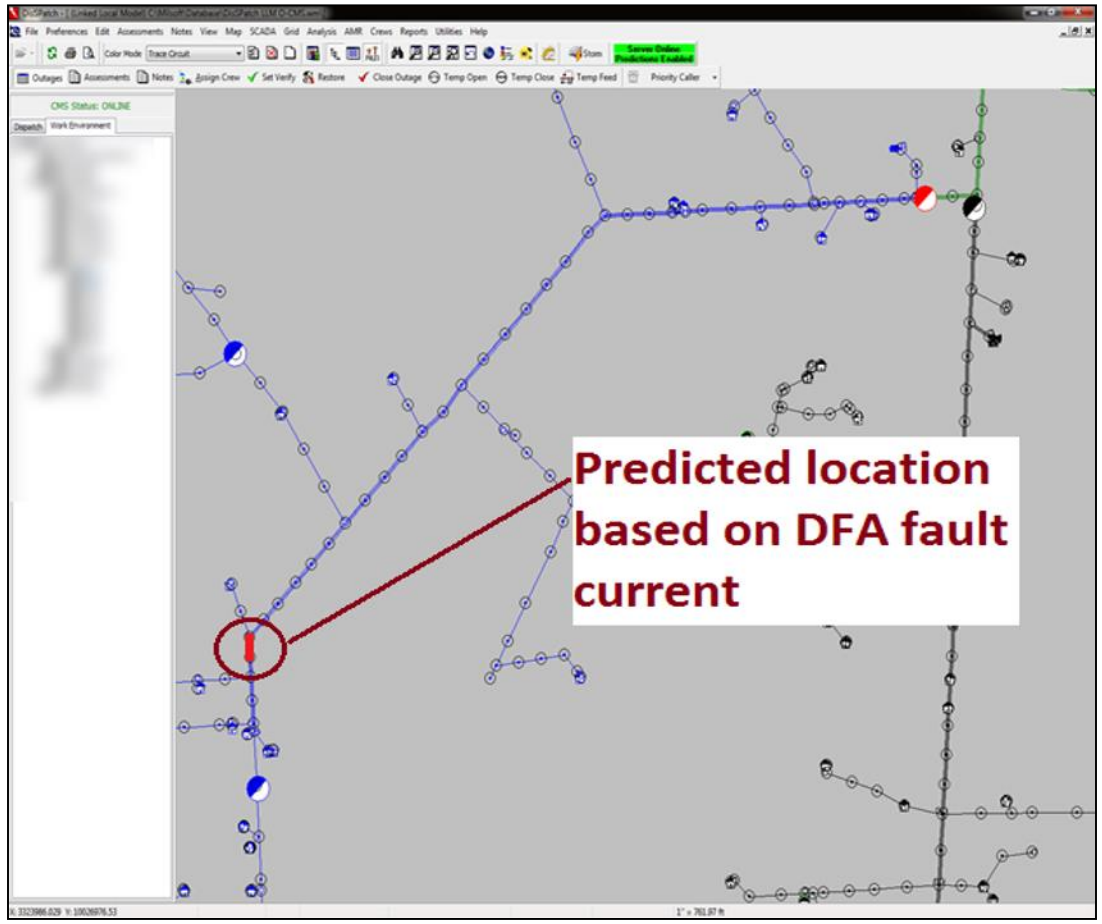
Arrester-Induced Fault and Outage



- Incident occurred on hot, fair-weather afternoon.
- Multiple members reported “blinks.” All were downstream of an unmonitored 70A recloser.
- Downstream of that recloser are 157 members and significant line miles (blue on map).
- Operator dispatched crews to search downstream of recloser.

Bluebonnet Use Case #1

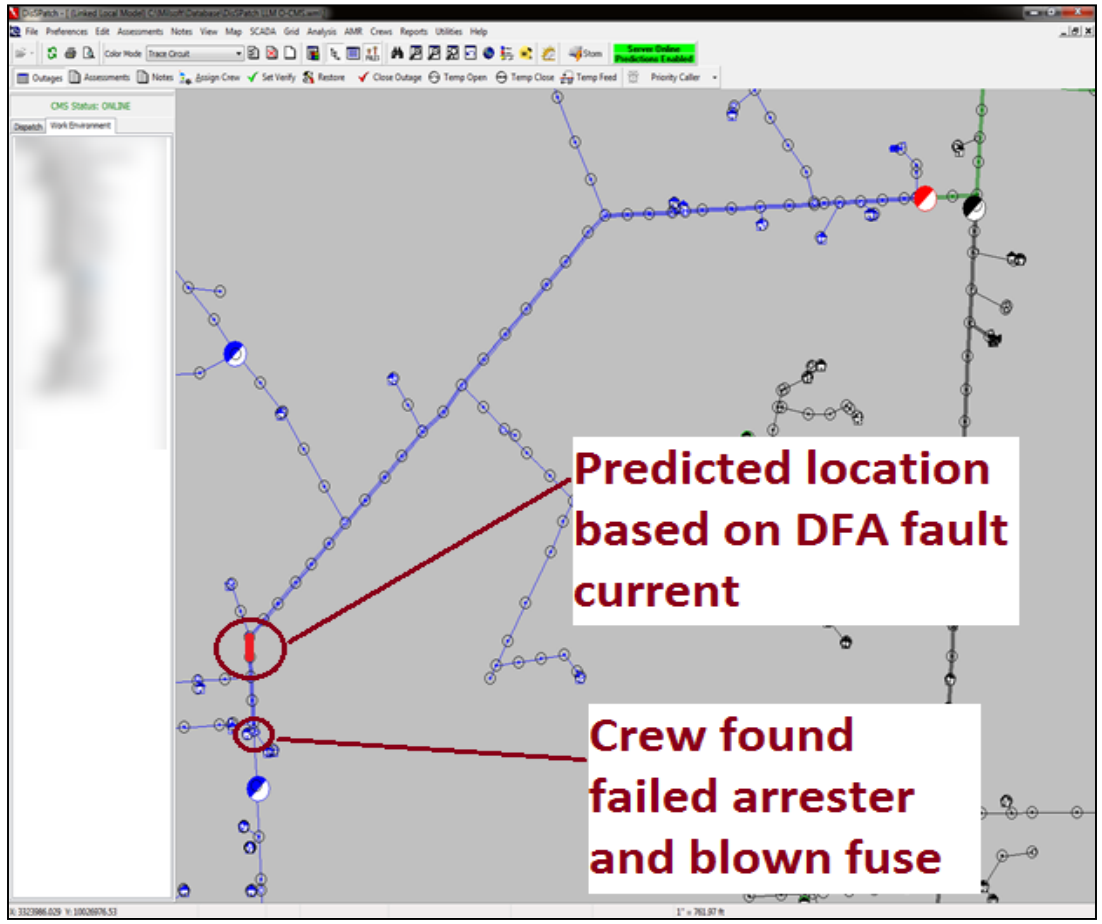
Arrester-Induced Fault and Outage (cont'd)



- Operator then received DFA-based fault alert that indicated:
  - Estimated fault current
  - Probable cause: failed arrester.
  - Prediction of cause came from manual analysis by Texas A&M.
- Operator redirected crews to the search area predicted by putting the DFA fault current estimate into the circuit model.

Bluebonnet Use Case #1

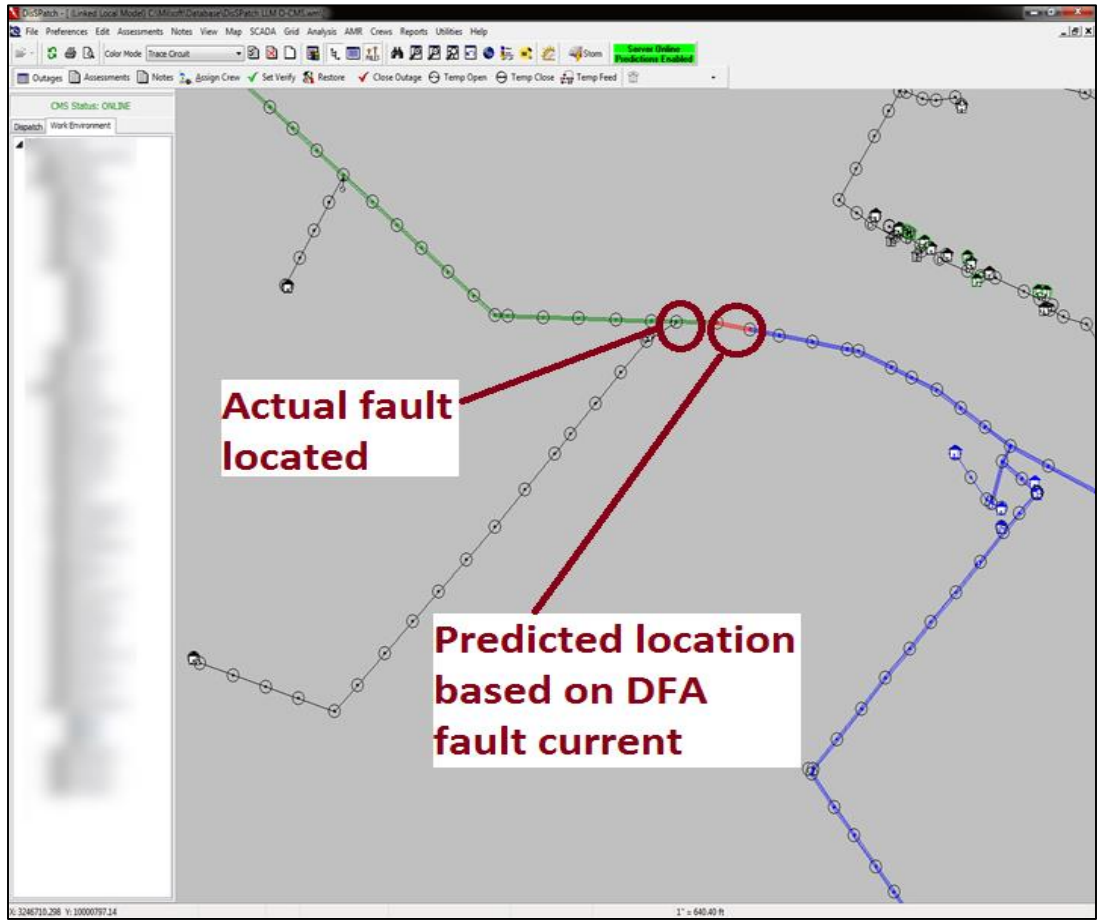
Arrester-Induced Fault and Outage (cont'd)



- The crew found a blown transformer fuse, caused by a blown arrester, three spans from the predicted location.
- Having the DFA report saved crew time (targeted search) and shortened the outage.
- Prediction of cause (failed arrester) was confirmed correct.

Bluebonnet Use Case #2

Outage Resolved without Member Call



- Operator noted DFA fault report and put DFA fault current estimate in model to predict location.
- Pinging meters in targeted area identified two meters out of service, one span from prediction.
- Crew found blown line fuse.
- Meters served water wells at an unmanned location. Without the DFA report, the outage may have persisted for a much longer period.

Bluebonnet Use Case #3

Failing Clamp

Expand	Substation	Circuit	Event Type	Phases	Amps	Amps	Count	Last Occurred
+	[redacted]	[redacted]	Probable failure of switch or clamp	A	25, -, -	40, -, -	79 transients (8 days)	2017-09-06 11:19:19

Event Type	Phases	Phase A Amps	Phase B Amps	Phase C Amps	Transients	Last Occurred
Probable failure of switch or clamp(I)	A	19	9	5	1	2017-09-06 11:19:19
Probable failure of switch or clamp(I)	A	16	3	5	1	2017-09-06 11:18:56
Probable failure of switch or clamp(I)	A	30	4	6	4	2017-09-06 11:18:34
Probable failure of switch or clamp(C)	A	20	4	4	2	2017-09-06 11:14:11

- A single member reported flickering lights.
- Lights were not flickering when trouble man was on-site. Tightened secondary connections and planned to emplace recording voltmeter.
- DFA reported ‘probable failure of switch or clamp.’
- Patrol of primary found failing clamp a few spans upstream. Replacement fixed issue.
- DFA enabled quicker resolution of the problem and fewer man-hours of labor.

Summary of Use of DFA at Bluebonnet

- Bluebonnet has begun using DFA, in concert with existing tools, to manage circuit operations.
- In multiple cases, DFA has enabled faster response, location, and restoration of outages, sometimes without ever receiving a call from a member.
- For faults investigated, Bluebonnet estimates that DFA-reported fault currents, used in conjunction with Bluebonnet's circuit models, put search crews within four pole spans 80% of the time.
- DFA has detected multiple capacitor issues, enabling generation of work orders for specific repairs to specific banks.
- DFA data has enabled Bluebonnet to diagnose the root cause of multiple complex failures (e.g., arcing inside capacitor on one circuit causing failure of an arrester on a different circuit).

Mid-South Synergy's Use of DFA Technology

Mid-South Use Case #1

Conductor on Wooden Crossarm (Broken Insulator)

- DFA detected two similar events on same circuit.
- Fault locating software was used to estimate possible locations.
- One of two possible reclosers had “seen” events that matched DFA.
- Crews were dispatched and they identified the problem a few spans from the model’s prediction.

Mid-South Use Case #1

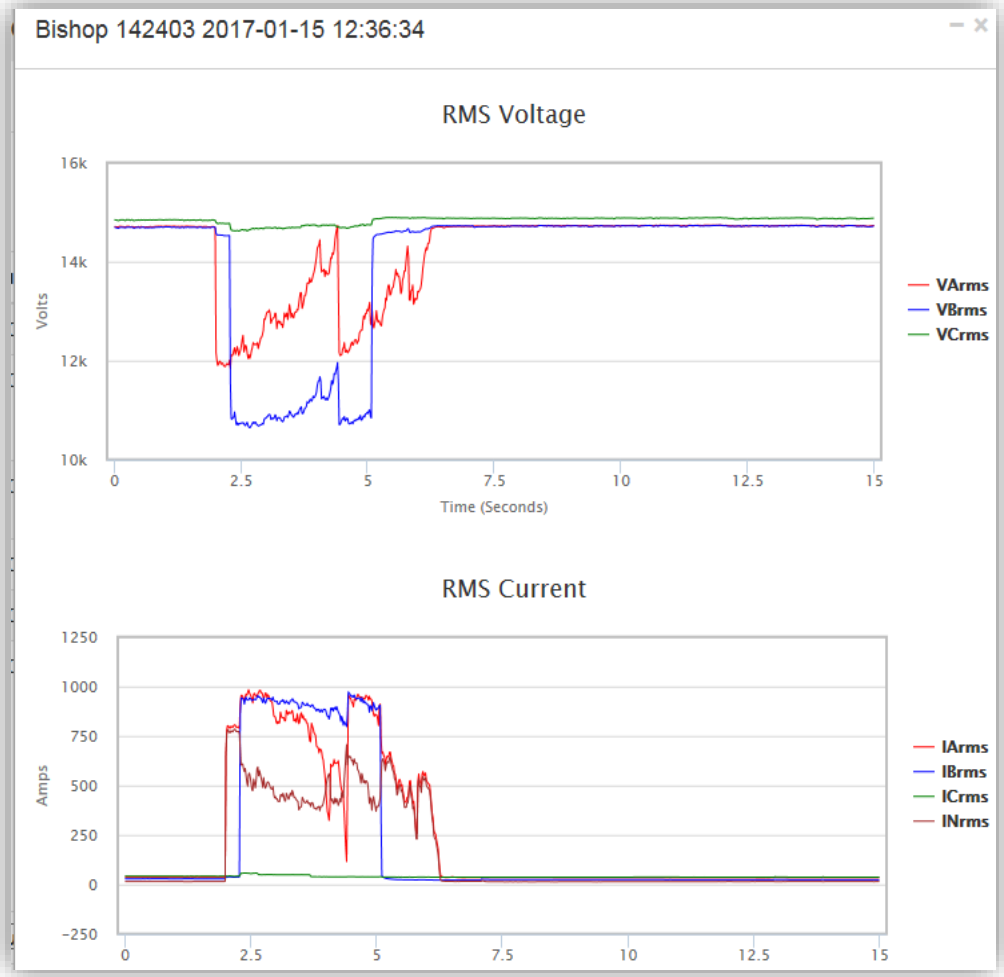
Conductor on Wooden Crossarm (Broken Insulator)

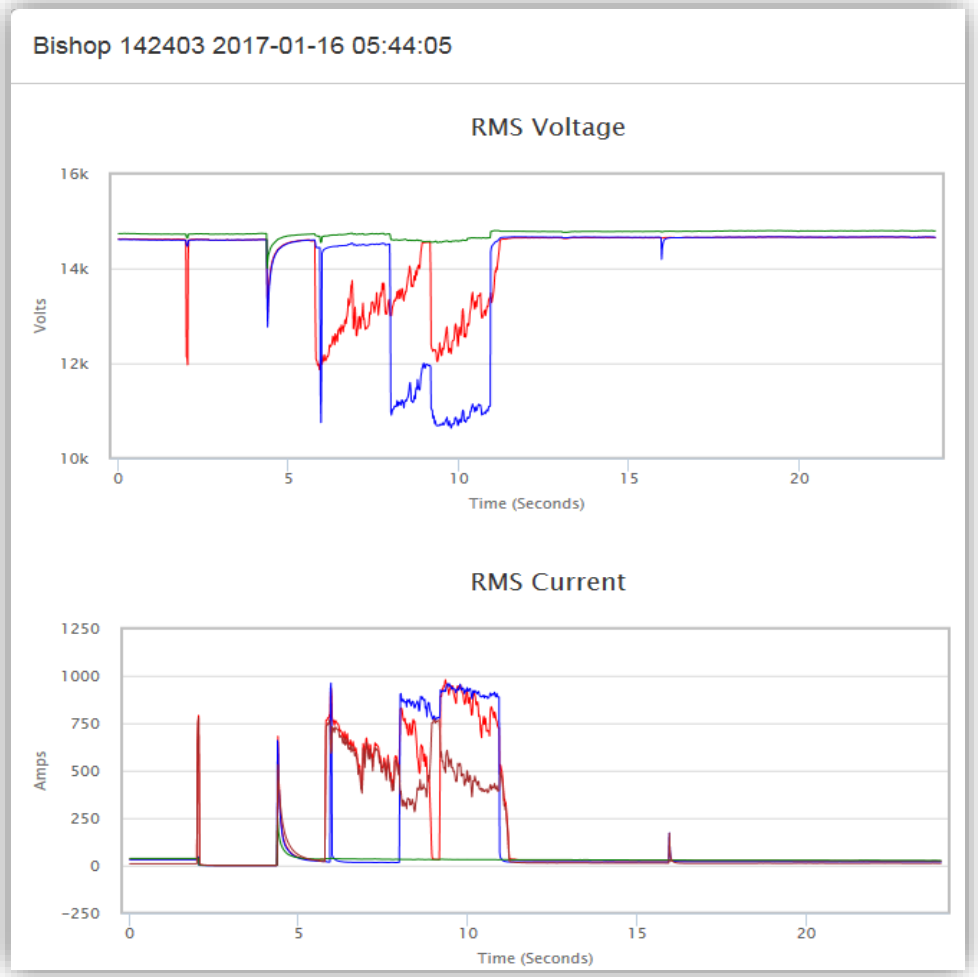
Circuit	Seen By	Event Type	Phases	Comments	Count	Last Occurred
142403	Bishop	Fault: Short lived	A	564 Amps (15 ms)	1	2017-01-23 13:23:02
142403	Bishop	Breaker reclose	AB	F-(3.0c,775A,AN)-T-2.3s-C-T-(-,-,-)%-1.4s-F-(313.0c,955A,ABN)	2	2017-01-16 05:44:05
142403	Bishop	Multi-phase reclose	AB	F-(211.5c,966A,ABN)-T-(4,33,18)%-2.0s-C	1	2017-01-15 12:36:34

- The screen grab above is directly from the DFA website. It provides a concise SOE for each fault, automatically, by analyzing CT/PT waveforms, without polling reclosers.
- Human analysis of waveforms is not required, but the waveforms are available if desired.
- In this particular case, the two faults were A-B-N and drew similar fault currents.

Mid-South Use Case #1

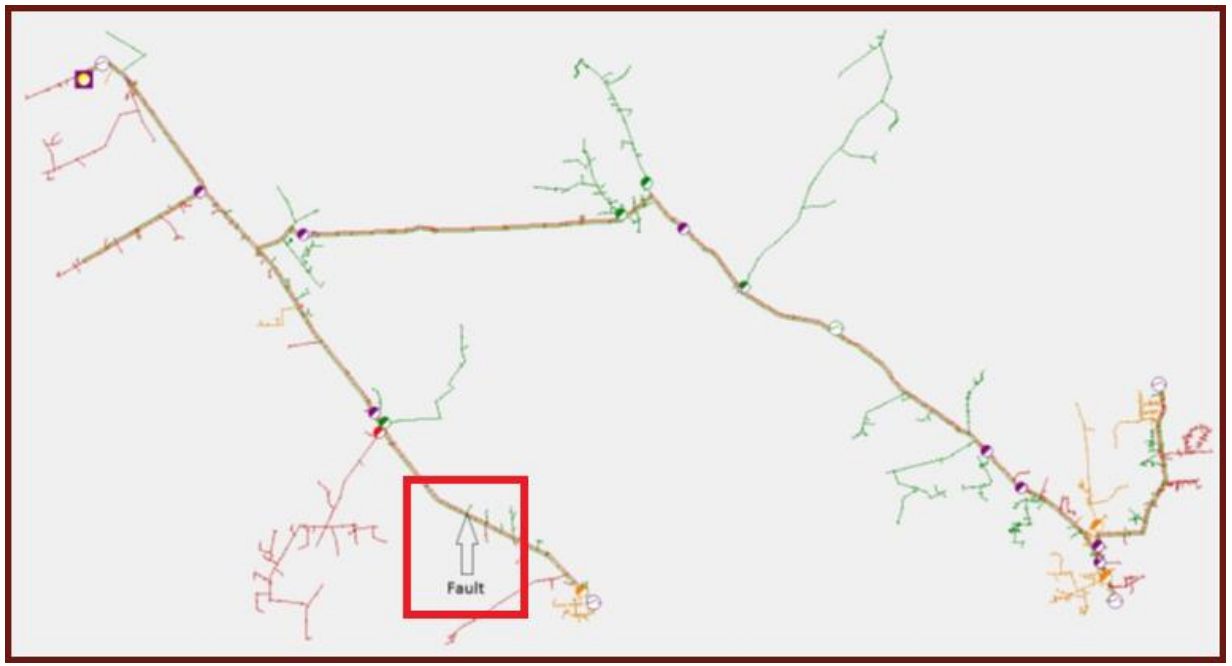
Conductor on Wooden Crossarm (Broken Insulator)





Mid-South Use Case #1

Conductor on Wooden Crossarm (Broken Insulator)



- Model-based software (Milsoft) identified two possible locations for the two faults.
- One of two possible reclosers had “seen” events that matched DFA.
- Crews were dispatched and they identified the problem a few spans from the model’s prediction.

Mid-South Use Case #1

Conductor on Wooden Crossarm (Broken Insulator)

Mid-South Use Case #1

Conductor on Wooden Crossarm (Broken Insulator)

Consequences Avoided

- Outage prevented, 140 members
- Possible broken conductor
- Possible pole fire
- Possible ignition of leaf litter and other dry material near base of pole

Mid-South Use Case #2

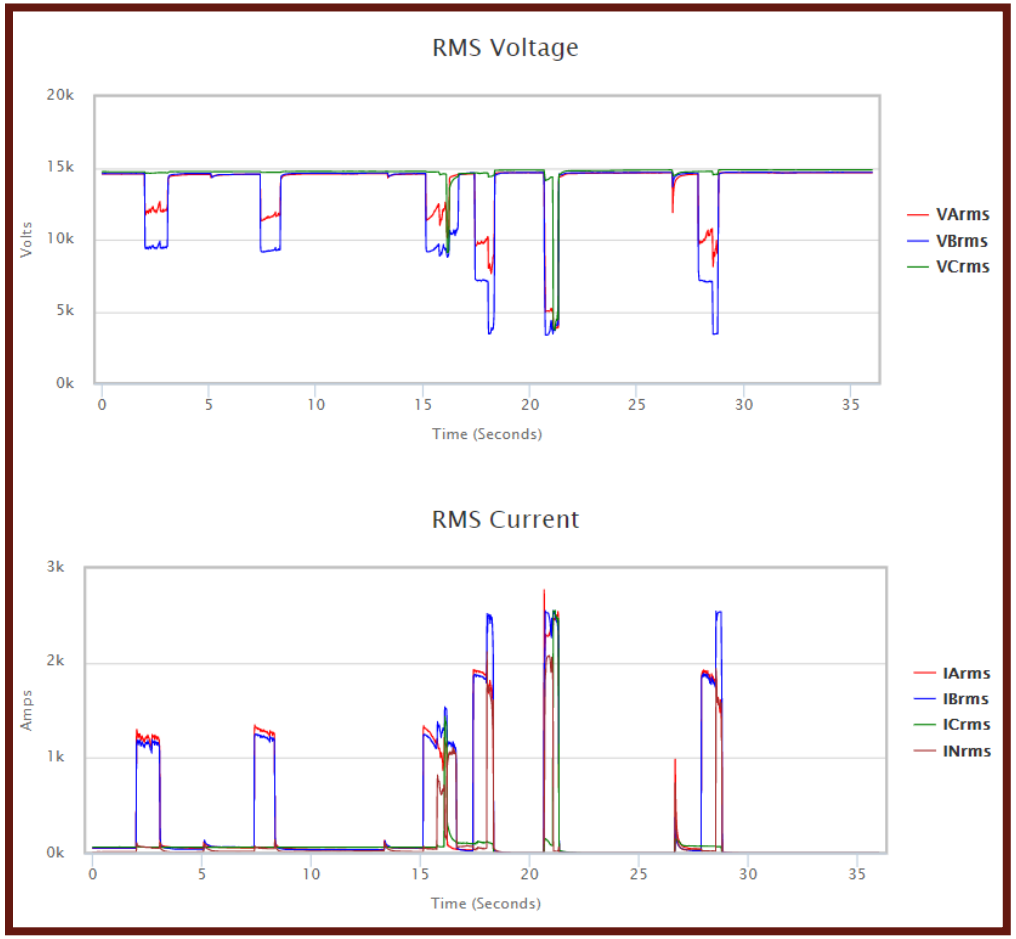
Complex Fault with Fault-Induced Conductor Slap

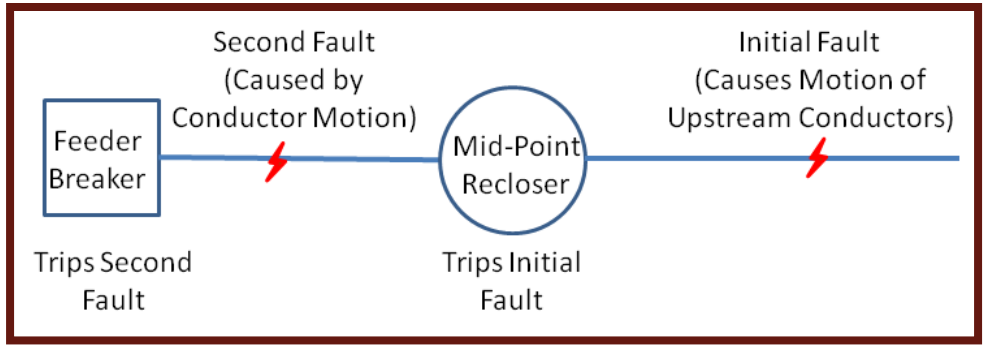
Possible conductor-slap	ABC	Breaker trip F-(91.5c,1495A,ABCN)-T-4.4s-C-20c-F-(30.5c,2519A,ABCN)-T-5.3s-C-F-(128.5c,2521A,ABN)-T	3 ops	2017-06-11 09:41:55

- A balloon caused a fault, which in turn caused an upstream jumper to fail. The substation breaker tripped the circuit.
- After restoring service, we found a report of conductor slap on the DFA website.
- Based on the DFA notice, and directed by Milsoft's Fault Locator function, a crew found "bright spots" on conductors, indicative of arcing.
- At the location, a homeowner told the crew he had witnessed the flash, which corroborated the DFA-based diagnosis of conductor slap.

Mid-South Use Case #2

Complex Fault with Fault-Induced Conductor Slap





- This incident involved fault-induced conductor slap, a mile upstream of the initial fault.
- Absent the DFA information, we would have been unaware of the conductor slap.
- As a consequence of this finding, we also are reviewing construction standards with regard to span lengths.

Conclusions

- Bluebonnet and Mid-South has used DFA to solve multiple problems of which conventional systems (e.g., SCADA, AMR/AMI, monitored reclosers, …) did not make them aware.
- Both have used DFA synergistically with existing tools (e.g., meter pings, monitored recloser data, circuit model software) to solve multiple problems.
- Current DFA deployments and future plans:
  - Bluebonnet has had 14 circuits fitted with DFA for about 18 months.
  - Mid-South Synergy has had 10 circuits fitted for a similar period.
  - Both anticipate adding DFA to more circuits in 2018.