

# **Automated Fault Analysis Using an Intelligent Monitoring System**

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# Background:

## Distribution Fault Anticipation (DFA) Project

- Goal – Document precursors of apparatus failures and faults
- Methodology
  - Instrument 60 feeders at 11 utilities
  - Sensitive record precursors and other phenomena
  - Investigate faults and failures to determine causality
  - Create database over multi-year period
- Outcomes
  - Extensive database of failures and precursors
  - Algorithms to recognize failures and improper device operations
  - Methods to automate processing, manage data, and present concise information

# Documented Failures

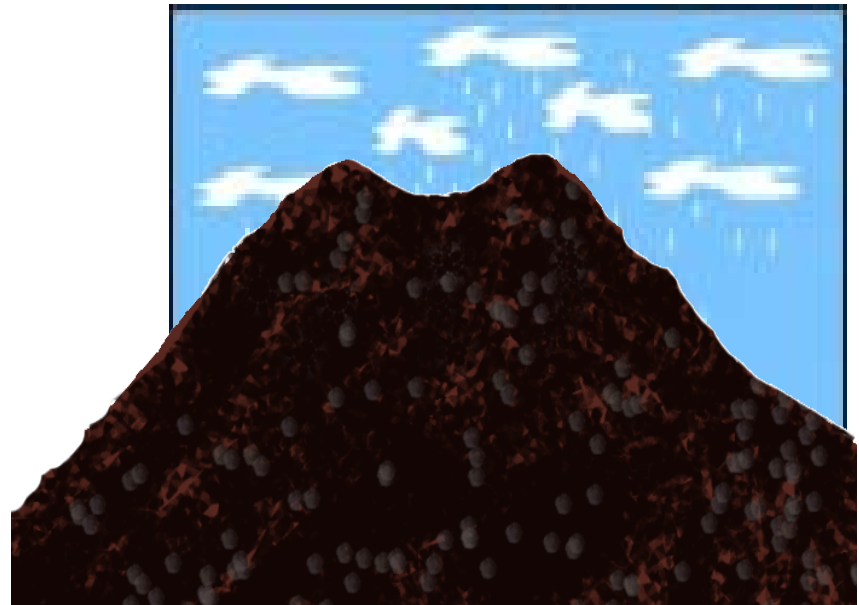
- Voltage regulator failure
- LTC controller failure
- Lightning arrestor failure
- Recurrent overcurrent faults
- Line switch/cutout failure
- In-line splice failure
- Cable failures
  - Main substation cable failure
  - Primary URD cable failure
  - Secondary overhead cable failure
  - Secondary URD cable failure
- Tree/vegetation contacts
  - Contacts with primary
  - Contacts with secondary services
- Overhead transformer bushing failure
- Overhead transformer winding failure
- URD padmount transformer failure
- Substation bus capacitor bushing failure
- Capacitor problems
  - Controller failures (excess operations)
  - Failed capacitors
  - Blown fuses
  - Switch restrike
  - Switch sticking
  - Switch burn-ups
  - Switch bounce
  - VAR tolerance problems
  - Pack failure

# Advances in Data Collection Devices: Solution or Just a Different Problem?

- Triggering sensitivity versus data volume
  - More sensitive triggering produces overwhelming data
  - Less sensitive triggering misses stuff
- Conventional tradeoffs limit data to maintain sanity!
  - Digital fault recorders (DFRs) record high-current faults.
  - Power quality (PQ) devices record voltage sags/swells that deviate 5-10 percent or more.
  - Relays clear faults and record those events.
- Finding more subtle problems requires more sensitive triggering and produces more data.
- Better, less expensive data devices create opportunities, but even more data.

# Mountains of Data

- Breaker operations alone can create a mountain of data.
- Downstream reclosers (including momentaries) grow mountain.
- Now consider more sensitive triggering, to capture subtle faults, failures, and other phenomena...

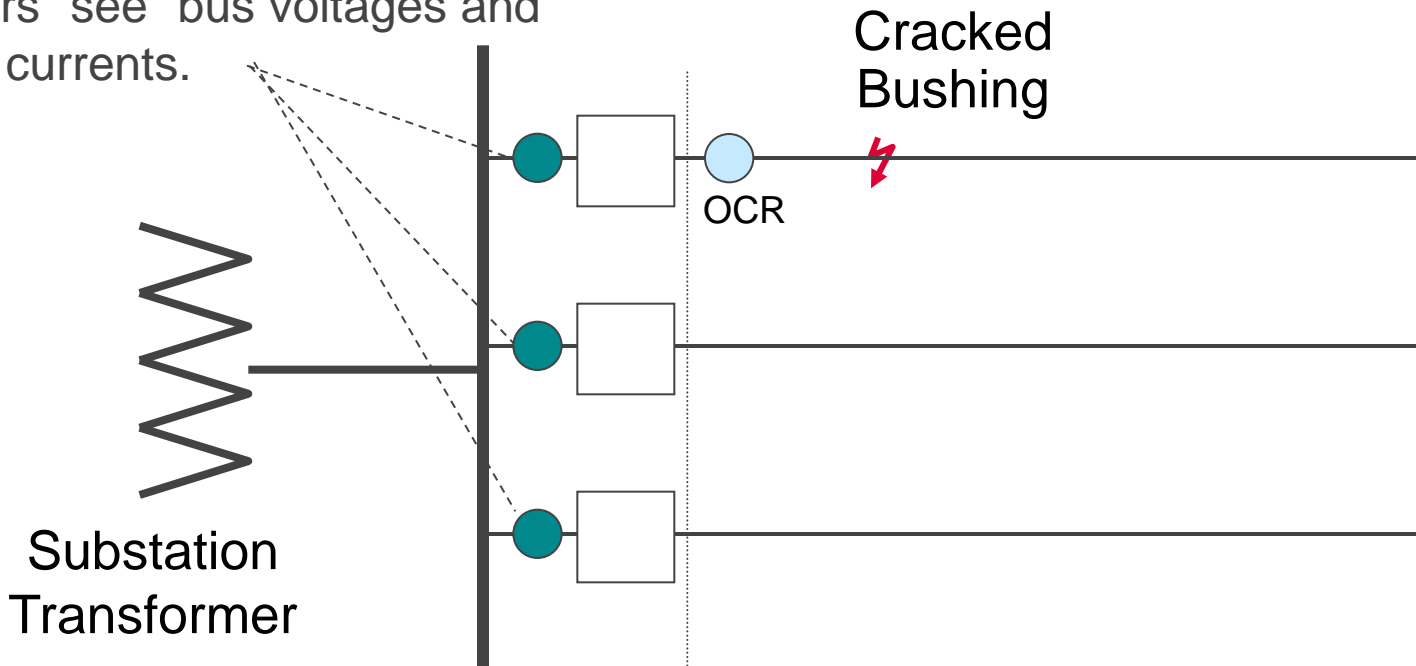


# Advances in Storage and Communications: Solution or Just a Different Problem?

- Traditional limitations were storage and communications.
- Advanced storage and communications are necessary but not sufficient to get value from data.
- Data concentrators provide useful storage tool, but you have to DO SOMETHING with all that data.
- Manpower-intensive analysis GUARANTEES underutilization.
- Automated analysis and concise reporting are absolute necessities to take advantage of embedded information.

# Demonstrative Example: Damaged Bushing

Monitors "see" bus voltages and feeder currents.



## Important Notes

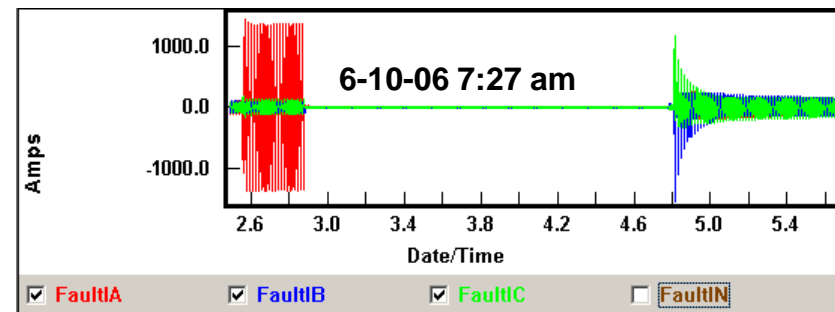
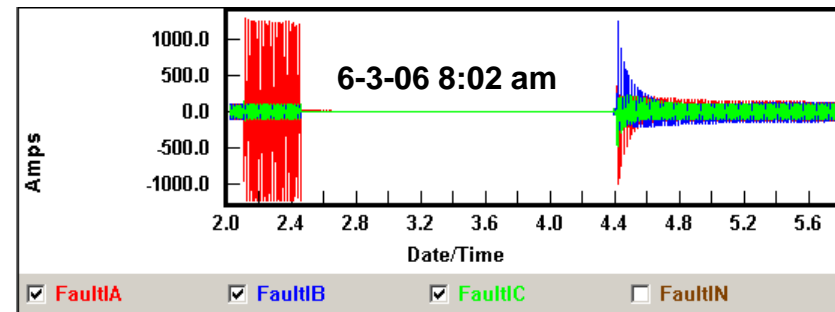
- All signals come from conventional CTs and PTs.
- No digital/status inputs were used (waveforms only).
- There was no communication to/from the subject pole-mount recloser.

# Damaged Bushing

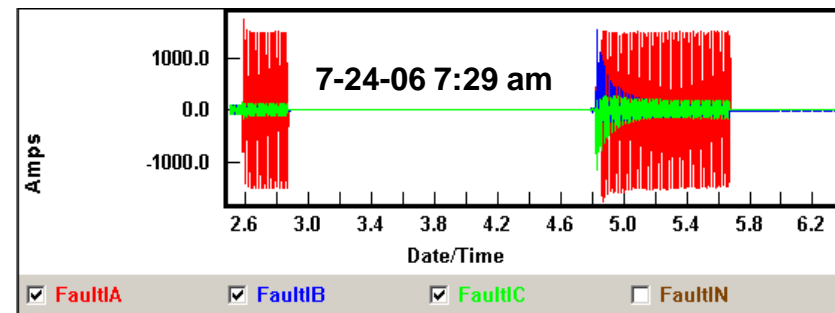
- 6-3-06 8:02 am First fault; no outage
- 6-10-06 7:27 am Second fault; no outage
- 6-17-06 10:16 am Third fault; no outage
- 6-24-06 8:29 am Fourth fault; no outage
- 6-28-06 7:32 am *Similar but unrelated fault*
- 7-4-06 6:07 am Fifth fault; no outage
- 7-24-06 7:29 am Sixth fault; sustained outage
- 7-24-06 8:04 am Power restored to all customers except those served by damaged transformer.

**Summary:** Six faults tripped close-in recloser at roughly one-week intervals. No customer complaints, outage, or notice to utility company.

**Result:** 35-minute outage to 903 customers (31605 CMI).



<6-17, 6-24, and 7-4 episodes not illustrated>



# What Did This Fault/Outage Happen?

- Fault occurred five times before outage.
- Utility engineer (and researchers) had data.
- Utility engineer (and researchers) had experience recognizing recurrent faults and avoiding outages.

***So why didn't somebody prevent this fault and outage?***

# What Did This Fault/Outage Happen?

- A week or more elapsed between individual episodes, with other "stuff" in between
- Nothing to prompt investigation
  - Pole-mount recloser, so there was no SCADA information.
  - Five momentary faults in six weeks is not that unusual on long circuit.
  - There were no customer complaints.
- Lack of expertise and time
  - Few have experience to recognize and diagnose.
  - Those with expertise have lots of other things to do.

*There is insufficient manpower to investigate every momentary interruption (even if you know about them!), especially since most are singular events and need no attention.*

# Utility Response to Damaged Bushing

## Current practice...

- 6/3/2006 Trip/reclose (unreported)
- 6/10/2006 Trip/reclose (unreported)
- 6/17/2006 Trip/reclose (unreported)
- 6/24/2006 Trip/reclose (unreported)
- 6/28/2006 *Unrelated trip/reclose (unreported)*
- 7/4/2006 Trip/reclose (unreported)
- 7/24/2006 Sustained outage
  - 903 customers
  - 35 minutes
  - 31 605 CMI

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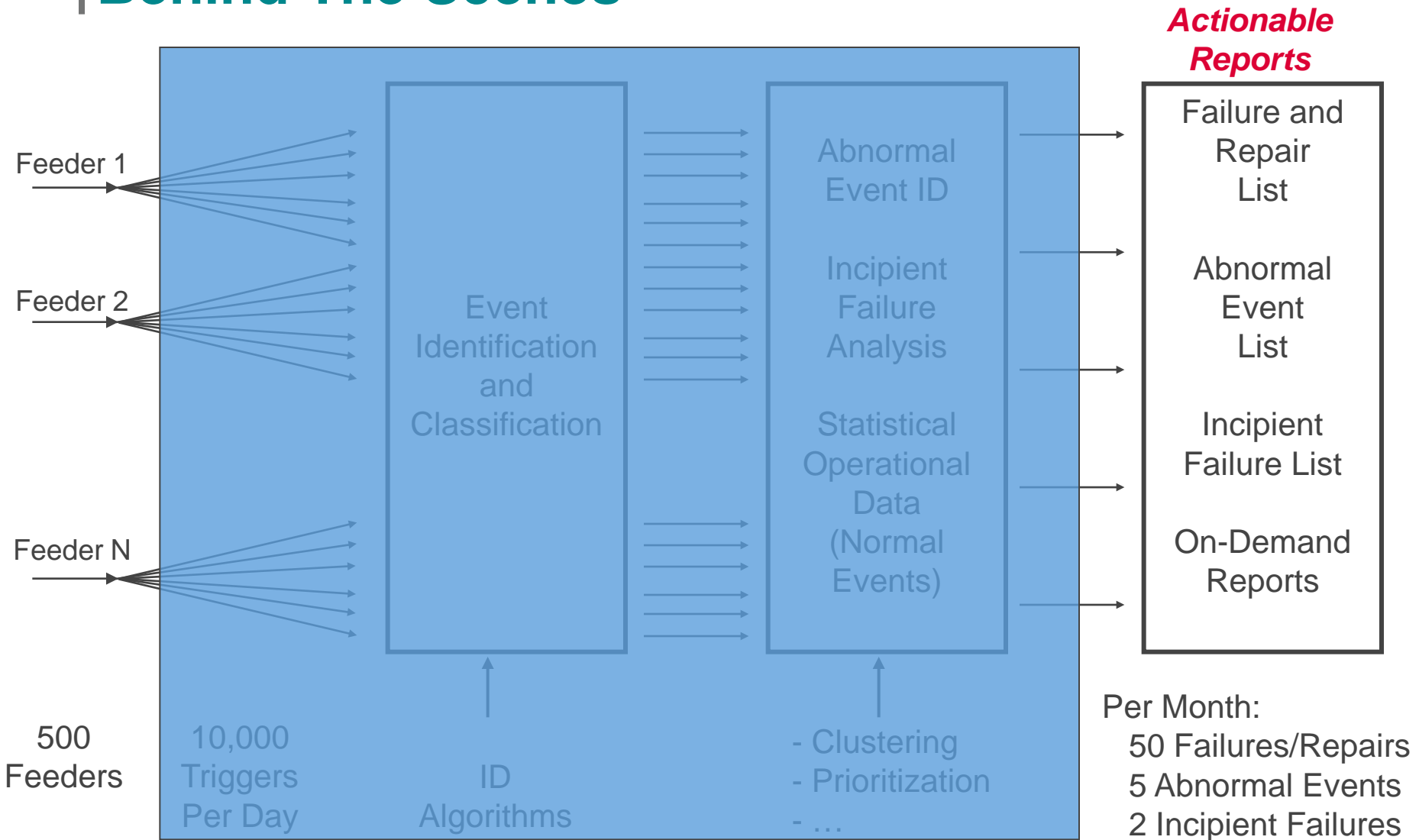
## With "Intelligence"...

- 6/3/2006 Trip/reclose
- 6/10/2006 Trip/reclose  
Generate alert
- 6/17/2006 Trip/reclose  
Prioritize alert
- 6/18/2006 Locate and repair failure
- 6/28/2006 *Unrelated trip/reclose*
- 7/4/2006 Avoided fault
- 7/24/2006 Avoided fault  
Avoided 31 605 CMI outage

## *Our choices:*

1. *Let the faults/outages happen (what we do now, without thinking about it!).*
2. *Spend a lot of time looking at data (which we don't have time to do!).*
3. *Utilize tools to automatically manage, analyze and report data.*

# Distribution Fault Anticipation Behind The Scenes



# DFA Alerts and Reports

Alerts Reports

Welcome Mr. Carl Benner Sign out

	Substation	Feeder	Seen By	Alert Type	Phases	Comments	Occurrences (7 days)	Last Occurred
<input type="checkbox"/>	Lakewood	7411	Sub	CAP: Excess operations	ABC	500, 492, 417 (φ kVARS)	232	<u>01/13/04 14:09:27</u>
	Lakewood	7411	Sub	Fault: Short lived	B	1441 Amps (11 ms)	1	<u>11/25/03 22:13:04</u>

Change page:  Change page:   Displaying page 1 of 1, items 1 to 2 of 2.

CAP: Excess operations	ABC	500, 492, 417 (φ kVARS)	232	<u>01/13/04 14:09:27</u>
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**1/13/04 Alert screen**  
**Excessive capacitor operations (232 in 7 days)**

# DFA Alerts and Reports

Alerts Reports

Welcome Mr. Carl Benner

Sign out

	Substation	Feeder	Seen By	Alert Type	Phases	Comments	Occurrences (7 days)	Last Occurred
	Lakewood	7411	Sub	Fault: Capacitor failure	A	2068 Amps	1	<a href="#">02/16/04 16:36:58</a>
+	Lakewood	7411	Sub	CAP: Excess operations	ABC	521, 505, 431 (φ kVARS)	225	<a href="#">02/16/04 13:37:08</a>
	Lakewood	7411	Sub	Fault: Short lived	B	1441 Amps (11 ms)	1	<a href="#">11/25/03 22:13:04</a>

Location  
Customize Alerts

Change page: < 1 > Change page: 1 Go Displaying page 1 of 1, items 1 to 3 of 3.

Fault: Capacitor failure	A	2068 Amps	1	<a href="#">02/16/04 16:36:58</a>
CAP: Excess operations	ABC	521, 505, 431 (φ kVARS)	225	<a href="#">02/16/04 13:37:08</a>

**2/16/04 Alert screen**  
**225 capacitor operations in 7 days, and phase-A capacitor has failed**

# DFA Alerts and Reports

Alerts Reports

Welcome Mr. Carl Benner Sign out

	Substation	Feeder	Seen By	Alert Type	Phases	Comments	Occurrences (7 days)	Last Occurred
+	Lakewood	7411	Sub	CAP: Excess operations	BC	-, 493, 411 (φ kVARS)	1404	<u>02/22/04 16:35:55</u>
	Lakewood	7411	Sub	Fault: Capacitor failure	A	2068 Amps	1	<u>02/16/04 16:36:58</u>
+	Lakewood	7411	Sub	CAP: Excess operations	ABC	521, 505, 431 (φ kVARS)	225	<u>02/16/04 13:37:08</u>
	Lakewood	7411	Sub	Fault: Short lived	B	1441 Amps (11 ms)	1	<u>11/25/03 22:13:04</u>

Change page: < 1 > Change page:  Go Displaying page 1 of 1, items 1 to 4 of 4.

CAP: Excess operations	BC	-, 493, 411 (φ kVARS)	1404	<u>02/22/04 16:35:55</u>
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***2/22/04 Alert screen  
Further accelerated operations (1404 in 7 days!)***

# DFA Alerts and Reports

Alerts Reports

Welcome Mr. Carl Benner

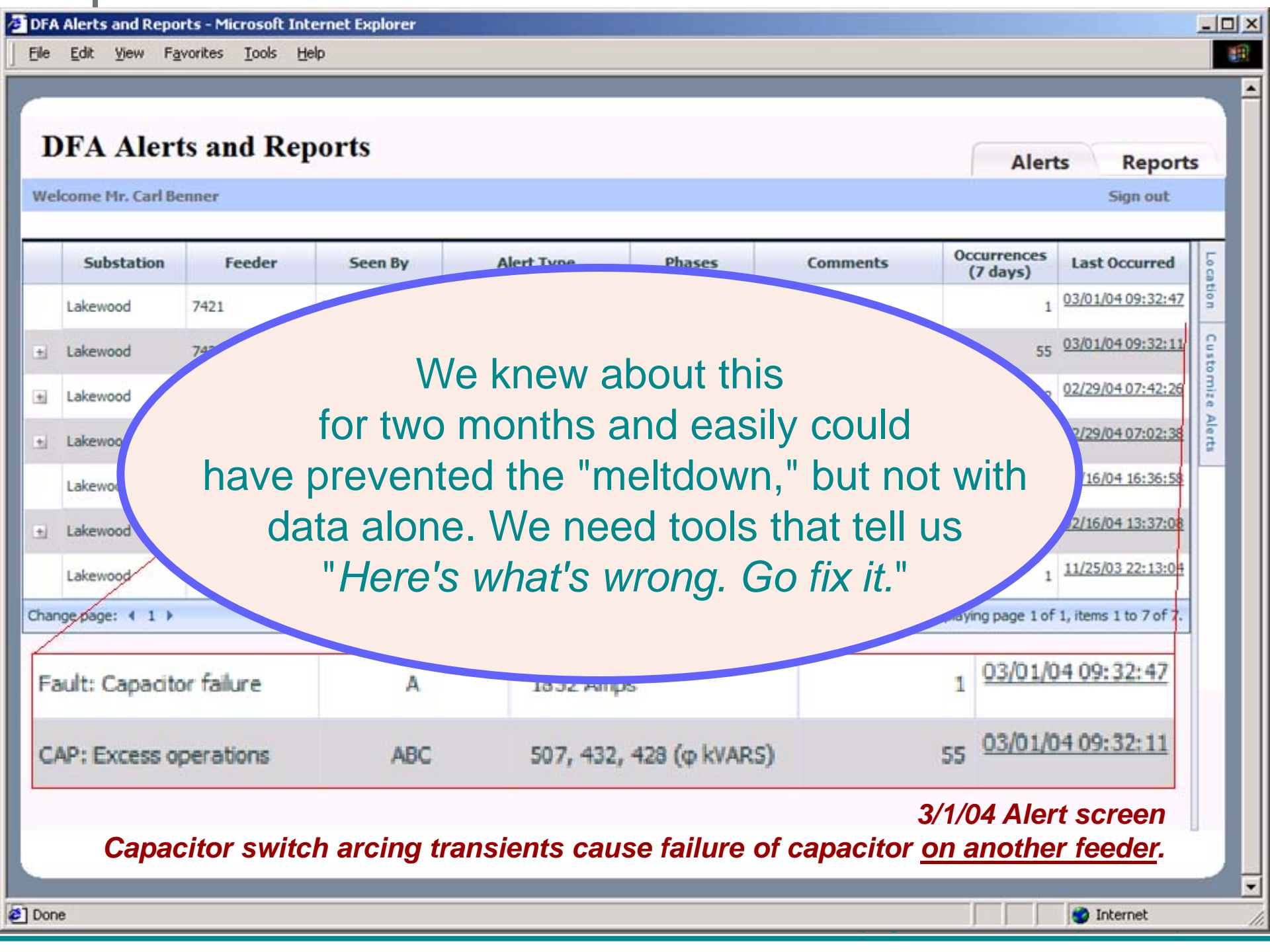
Sign out

	Substation	Feeder	Seen By	Alert Type	Phases	Comments	Occurrences (7 days)	Last Occurred	Location
+	Lakewood	7411	Sub	CAP: Arcing switch, can or connection	ABC	-, -, - (φ kVARS)	52	<a href="#">02/29/04 07:42:26</a>	Customize Alerts
+	Lakewood	7421	Sub	CAP: Excess operations	ABC	503, 434, 428 (φ kVARS)	54	<a href="#">02/29/04 07:05:08</a>	
+	Lakewood	7411	Sub	CAP: Excess operations	BC	-, 492, 411 (φ kVARS)	594	<a href="#">02/29/04 07:02:38</a>	
	Lakewood	7411	Sub	Fault: Capacitor failure	A	2068 Amps	1	<a href="#">02/16/04 16:36:58</a>	
+	Lakewood	7411	Sub	CAP: Excess operations	ABC	521, 505, 431 (φ kVARS)	225	<a href="#">02/16/04 13:37:08</a>	
	Lakewood	7411	Sub	Fault: Short lived	B	1441 Amps (11 ms)	1	<a href="#">11/25/03 22:13:04</a>	

Change page: 1 Change page: 1 Go Displaying page 1 of 1, items 1 to 6 of 6.

CAP: Arcing switch, can or connection	ABC	-, -, - (φ kVARS)	52	<a href="#">02/29/04 07:42:26</a>
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**2/29/04 Alert screen**  
**Overworked capacitor switch contacts begin arcing.**



# DFA Alerts and Reports

Alerts

Reports

Welcome Mr. Carl Benner

Sign out

Substation	Feeder	Seen By	Alert Type	Phases	Comments	Occurrences (7 days)	Last Occurred	Location
Lakewood	7421					1	03/01/04 09:32:47	
+ Lakewood	7421					55	03/01/04 09:32:11	Customize Alerts
+ Lakewood							02/29/04 07:42:26	
+ Lakewood							02/29/04 07:02:38	
Lakewood							01/16/04 16:36:58	
+ Lakewood							02/16/04 13:37:08	
Lakewood						1	11/25/03 22:13:04	

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Fault: Capacitor failure	A	1832 Amps	1	03/01/04 09:32:47
CAP: Excess operations	ABC	507, 432, 428 (φ kVARS)	55	03/01/04 09:32:11

**3/1/04 Alert screen**

**Capacitor switch arcing transients cause failure of capacitor on another feeder.**

DFA Alerts and Reports - Windows Internet Explorer

https://epridfa.tamu.edu/DFAREports/Alerts.aspx?type=reports&to=12-25-08

DFA Alerts and Reports

Welcome Carl Benner | Change Password | Sign Out

Displaying reports for: All Utilities

Daily Weekly Monthly History

Overcurrent Report (By time) Overcurrent Report (By Magnitude) Capacitor Report Arcing Report

Feeder	Condition	Phases	Phase A WAPS	Phase B WAPS	Phase C WAPS	Occurren...	Last Occurred
13-Q-2	CAP: Unbalanced						12/22/08 23:17:00
25F63	CAP: Arcing switch						
	Ev...						
	CAP: Arcing switch						
	CAP: Arcing						
	CAP:						
	CAP:						
036							

Automated reporting told us, "Here's what's wrong. Go fix it," and we did, thereby avoiding escalation and damage of other feeder apparatus.

25F63	CAP: Arcing switch					0	17	12
Event Type		Phases			Occurred			
CAP: Arcing switch, can or connection		C			12/22/08 15:24:48			
CAP: Arcing switch, can or connection		C			12/22/08 15:24:30			

# Summary

- Data holds clues to improving operations and reliability, but raw data overwhelms.
- Manpower-intensive treatment of data **GUARANTEES** underutilization.
- Need automated data management, automated analysis, and concise reporting.
- Current status of technology
  - Pilot trials are ongoing and others are being planned.
  - Currently demonstrating techniques to provide useful information from data, but much additional value remains to be exploited.
  - Texas A&M has membership-based consortium to advance technology.
  - Also exploring adaptation of concepts to transmission systems.

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