Development and Demonstration of Advanced Monitoring Systems for Fault Location, Analysis, and Prediction

Mark McGranaghan
EPRI Solutions
May 25-26, 2006

Outline

- Project Overview
- Project Objectives
- Project Plan – Two parts to project
  - Fault Anticipation Technology Demonstration
  - Data Integration for Disturbance Library
- Partners
- Budget and Status

Project Overview

- Part of overall objective to improve reliability and efficiency of operating electric distribution systems.
- Automated approaches for identifying and locating problems
- Approaches for existing monitoring systems
- New monitoring technologies (Distribution Fault Anticipator)
- National Disturbance Library

Project Objectives

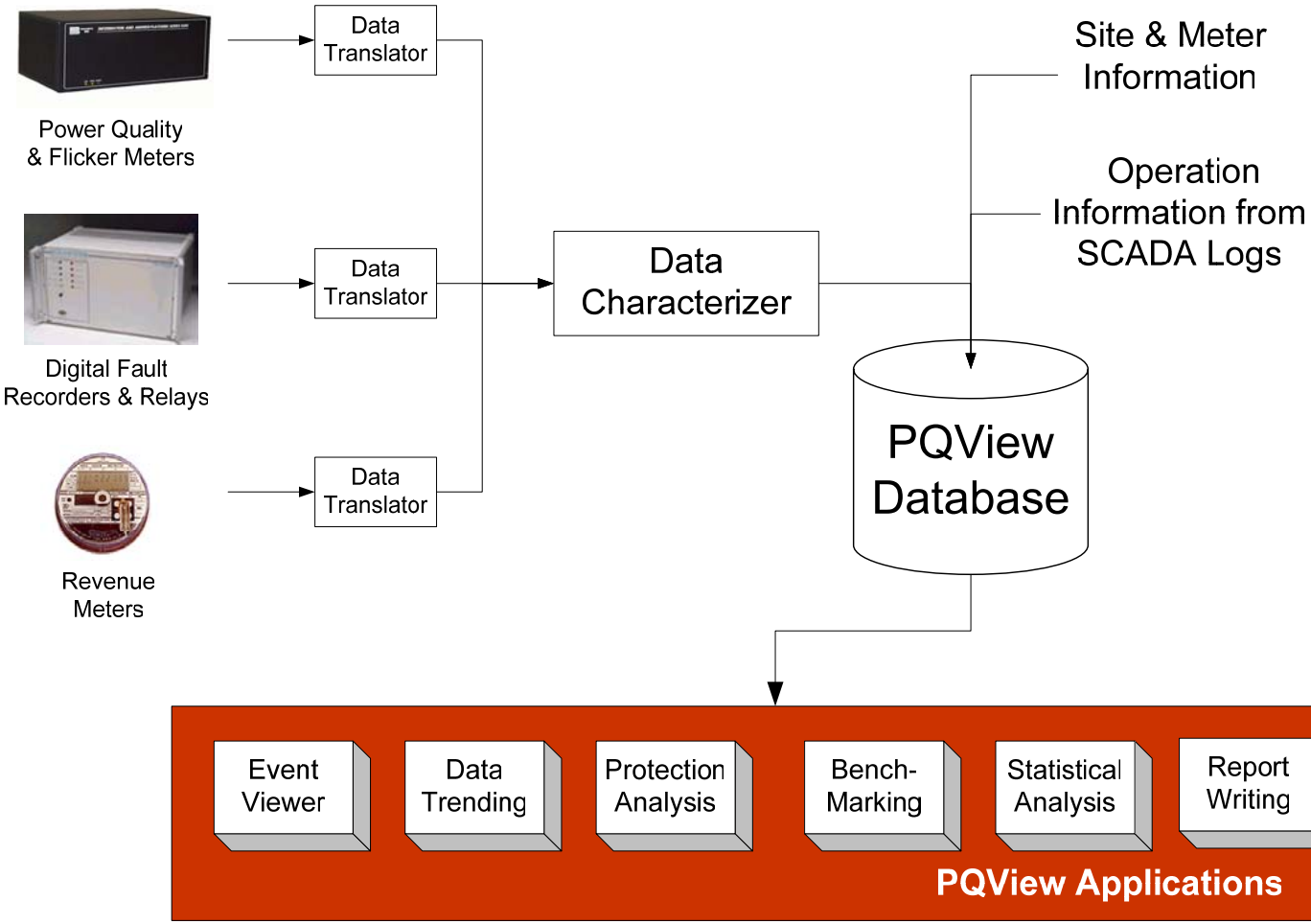
- Technology Assessment
- Design and implement a National disturbance data library
  - Database design and implementation
  - Coordinate utility contributions
- Develop and demonstrate advanced distribution fault anticipator system
  - Implement enhancements to the DFA system (EPRI-funded) based on input from DFA Focus Group.
  - Evaluate the performance in actual field applications.
  - Develop recommendations for technology and algorithms in actual field applications.

EPRI Solutions

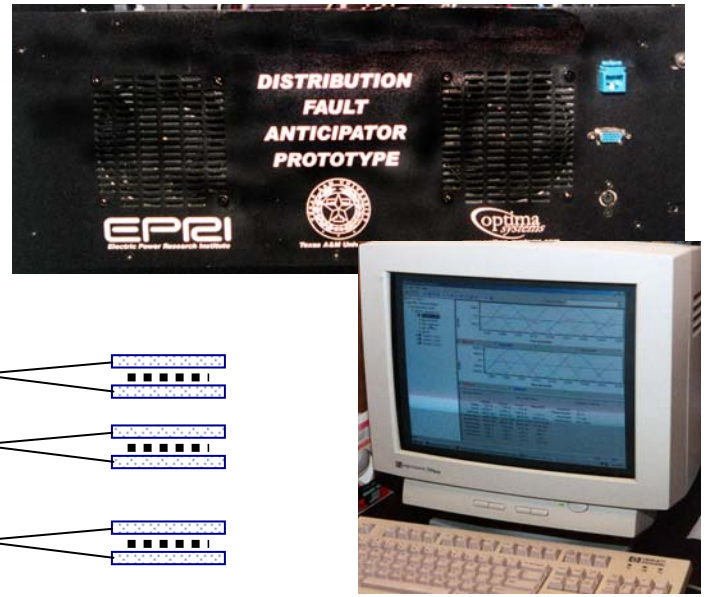
Texas A&M
and
Power Solutions, Inc.

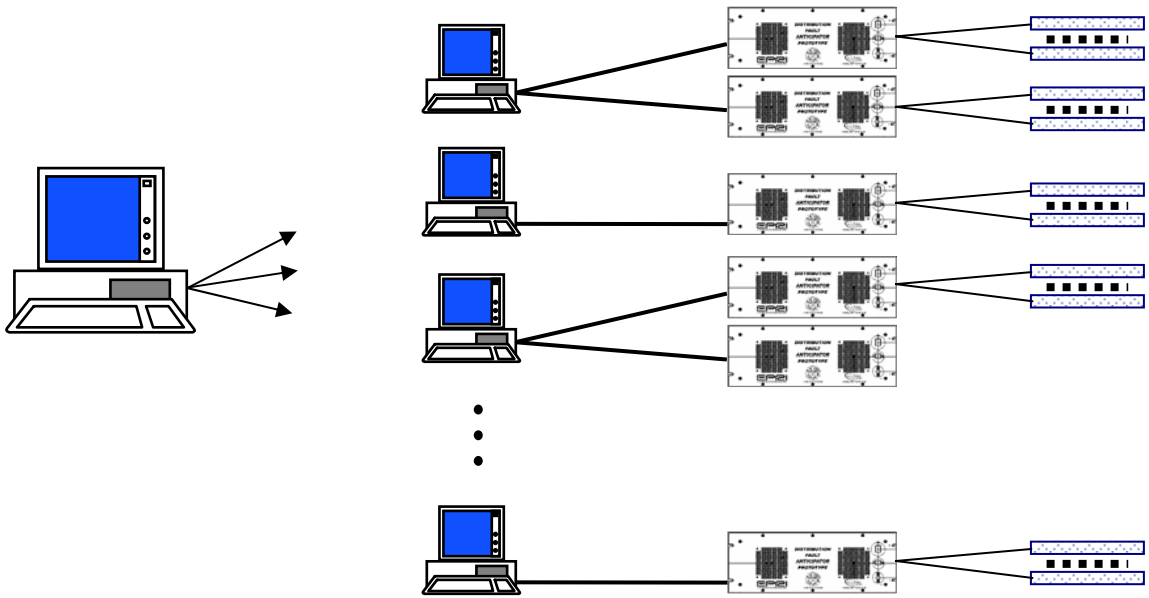
Building on Existing Platforms

PQView® Architecture



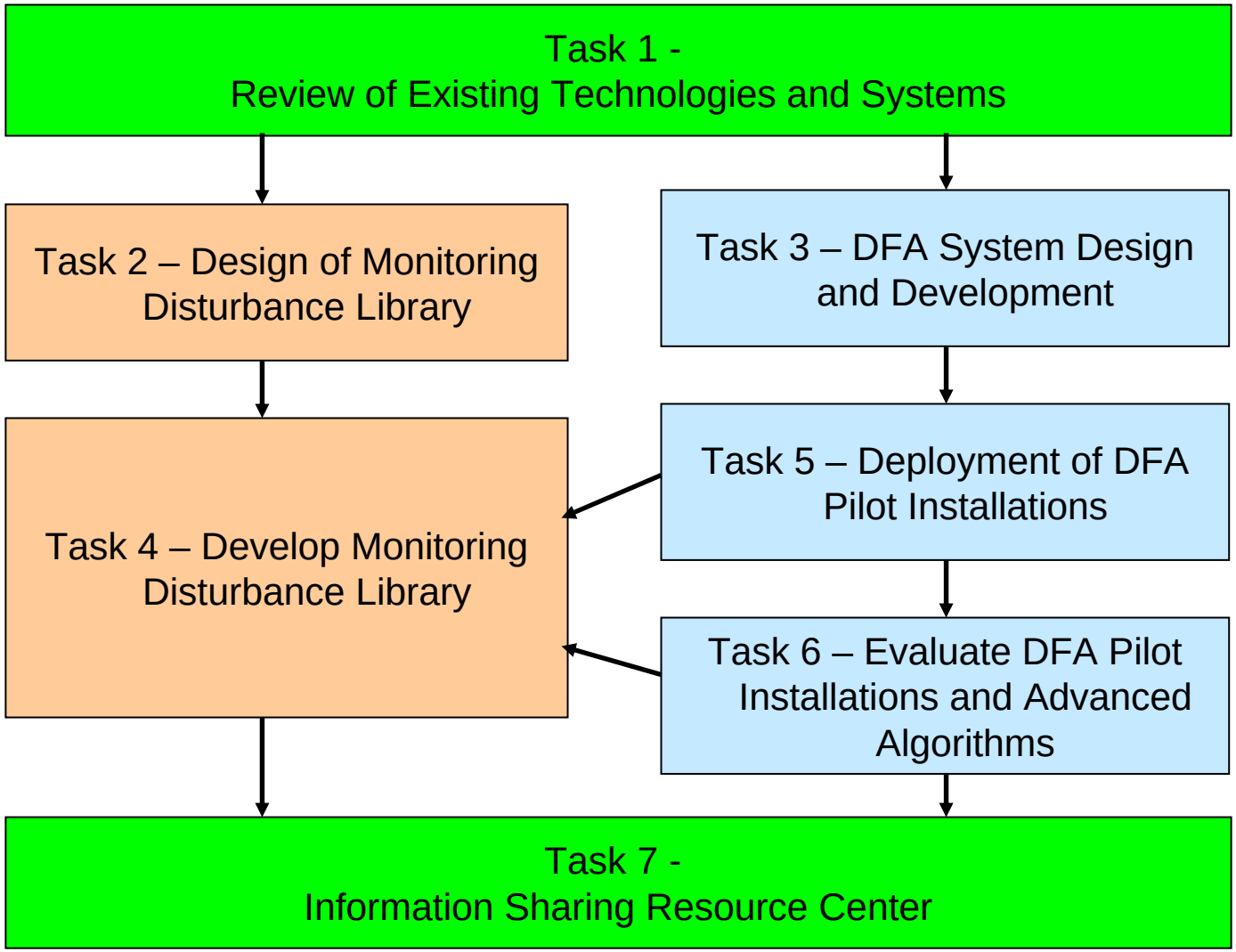
Building on Existing Platforms – DFA





Master Master Station (TAMU HQ) | **11 Utility Companies** | **14 Substations 14 Monitoring Units** | **60 Monitored Circuits**

Project Structure



Partners

- **TXU Electric Delivery**
- **Southern Company**
- **American Electric Power (AEP)**
- **Tennessee Valley Authority (TVA)**
- **Consolidated Edison**
- **San Diego Gas & Electric (SDG&E)**
- **United Illuminating (UI)**
- **Progress Energy Carolina**

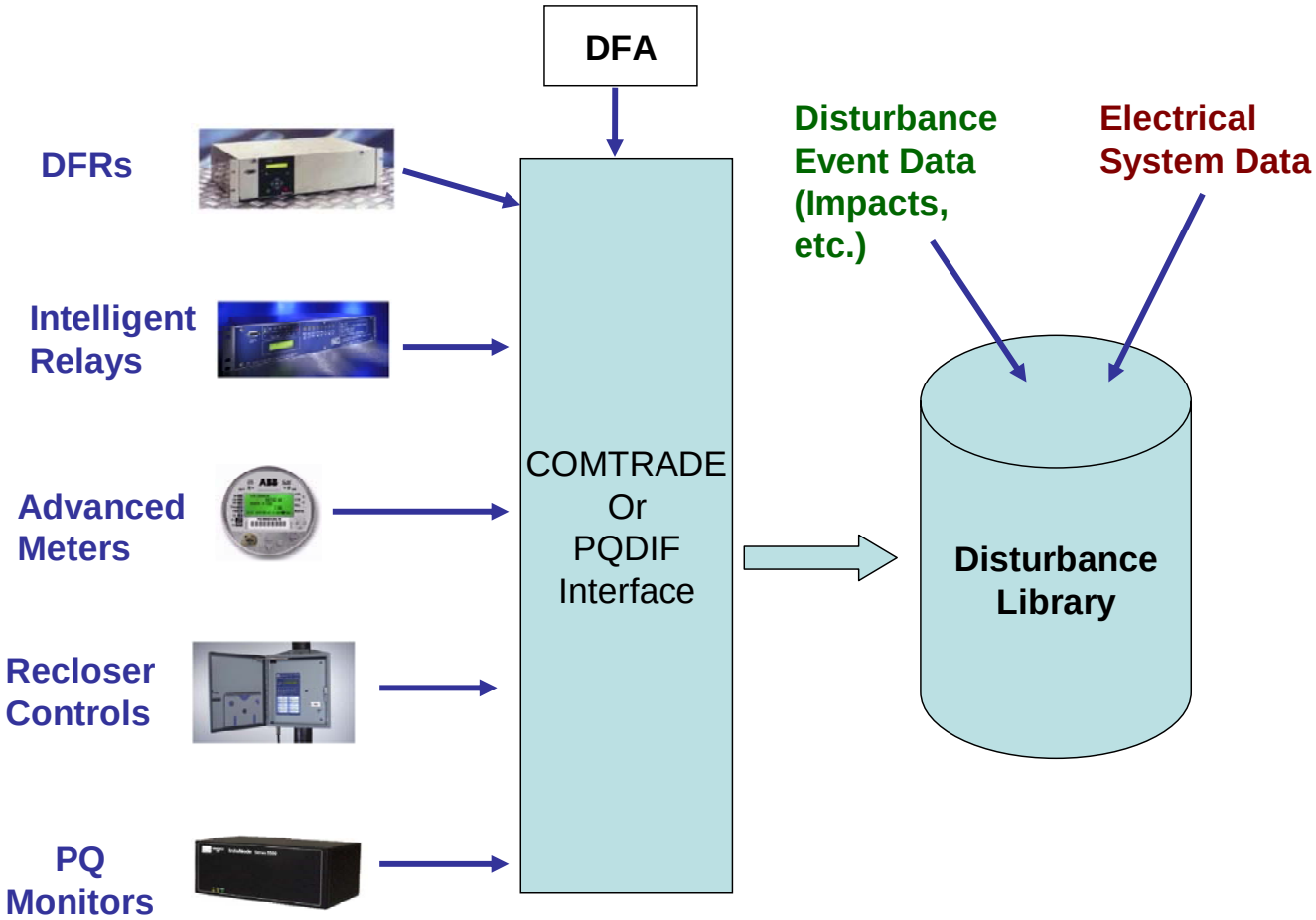
Contributions from utilities for DFA Development

- DFA Focus Group – provide input on DFA requirements for commercial application
  - Managed by TXU
- DFA demonstrations
  - Substation application – TXU
  - Feeder applications – Southern Company

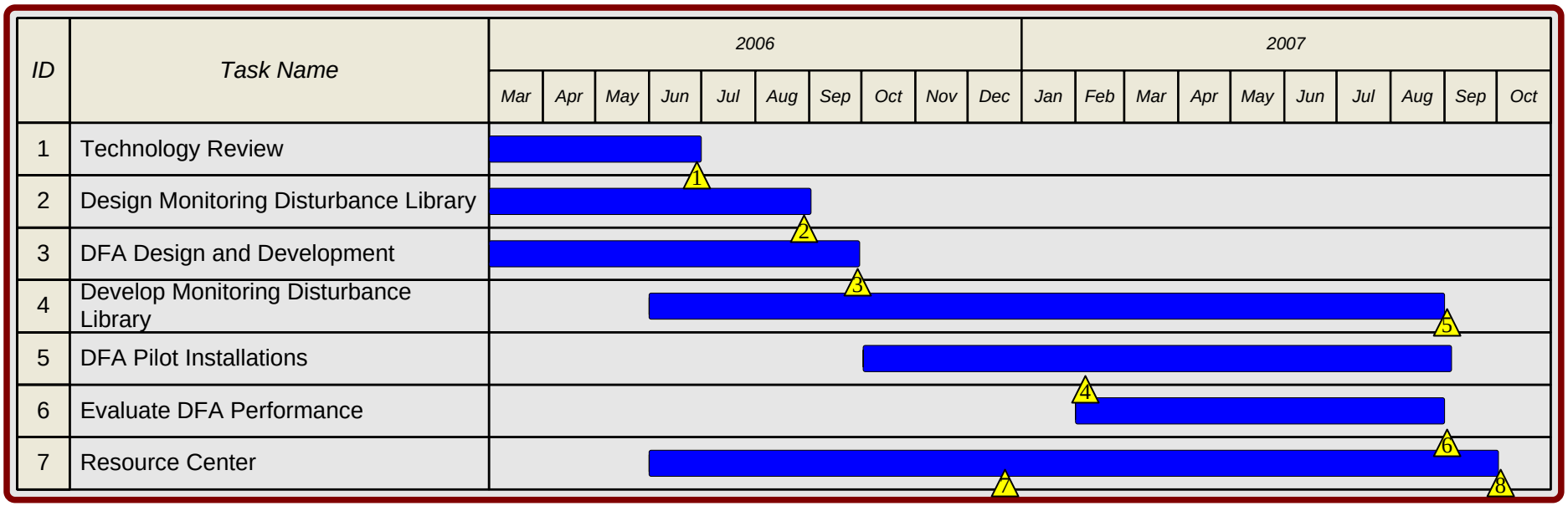
Contributions from each utility to the Disturbance Library

- System descriptions for selected distribution systems
- Monitoring data from these distribution systems
  - PQDIF
  - COMTRADE
  - PQVIEW Database
- Documentation for disturbances
  - Event descriptions
  - Equipment impacts
  - System conditions
  - Other info

Data Integration for Disturbance Library



Schedule



1. Technology Review
2. Disturbance Library Design Document
3. DFA Design Plan
4. DFA Pilot Installations
5. Monitoring Disturbance Library
6. DFA Performance Assessment
7. Resource Center Design
8. Final Report and Resource Center

Budget

	2006	2007	Total
EPRI Solutions	$240,000	$210,000	$450,000
Subcontracts (Texas A&M and Power Solutions, Inc)	$377,000	$173,000	$550,000
Total DOE Funding	**$617,000**	**$383,000**	**$1,000,000**
Utility Partners	$1,116,000	$693,000	$1,809,000
Total Project	**$1,733,000**	**$1,076,000**	**$2,809,000**

Deliverables – National Disturbance Library

- Design Document for National Disturbance Library
  - Standard architectures for the databases
  - Standards for data exchange
  - Access methods
- Database Demonstration
- National Disturbance Library
  - Accessible by public via the Internet
  - Available for developing, evaluating, and testing advanced algorithms to improve the performance of distribution systems

Deliverables – DFA System Design and Development

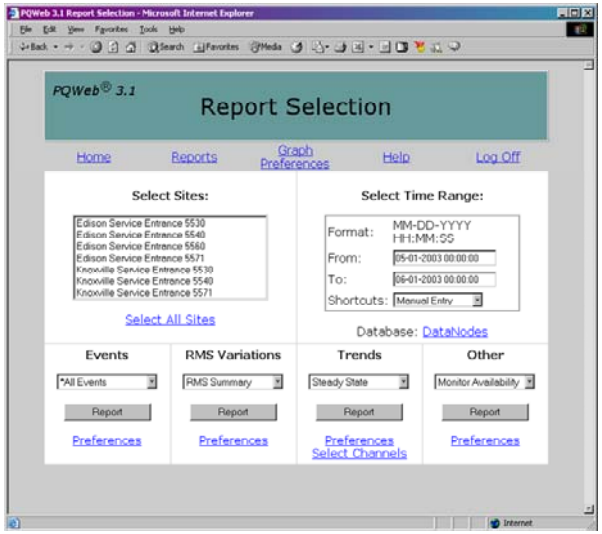
- Updated DFA Design based on input from DFA Focus Group
- Integration of DFA with information systems (including National Disturbance Library)
- Prototype demonstrations of DFA applications at TXU and Southern Company

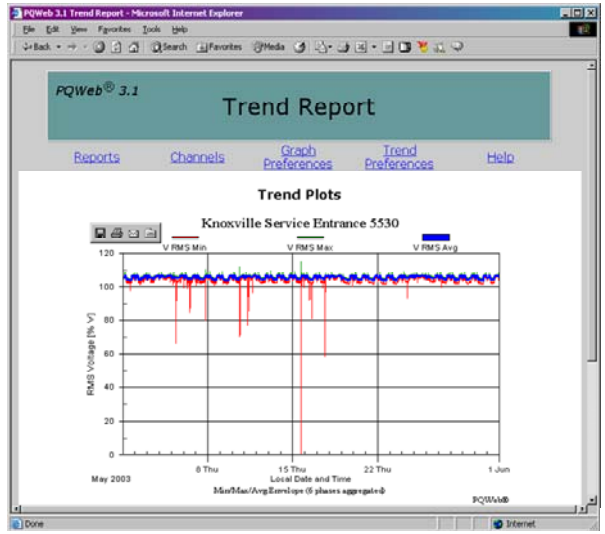
Deliverables – Advanced Monitoring Information Resource Center

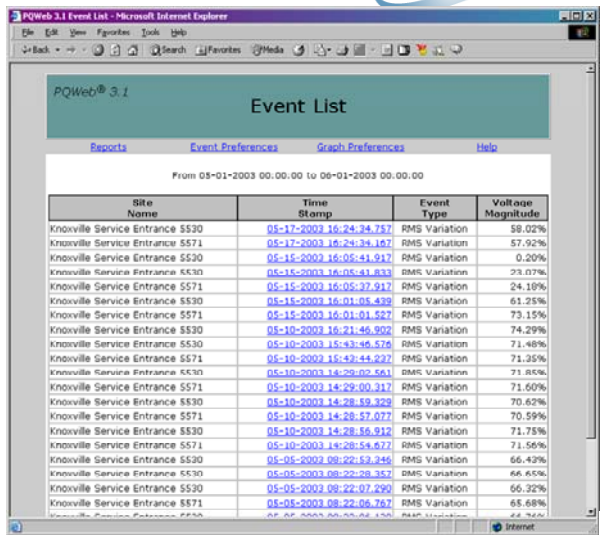
- Web site structure for sharing information and data
- Disturbance library implementation on the web site
- Database of intelligent applications implementation
- Reference material and links to other activities

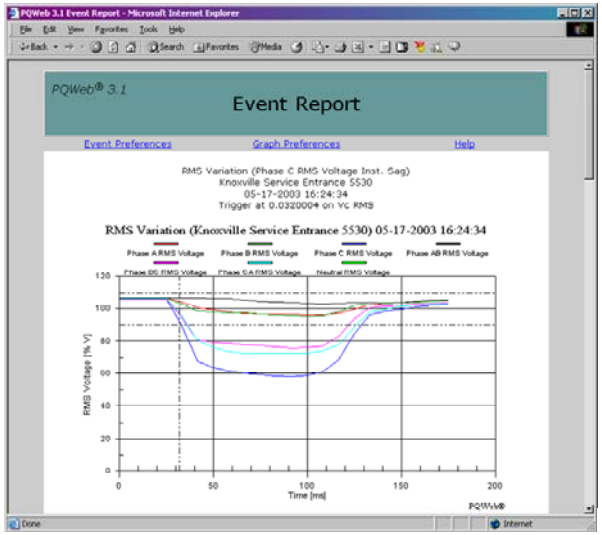
www.advancedmonitoring.com

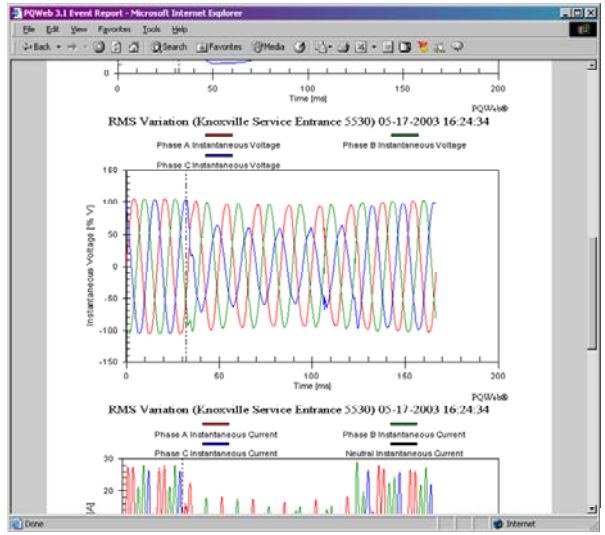
Web-Based Access to System

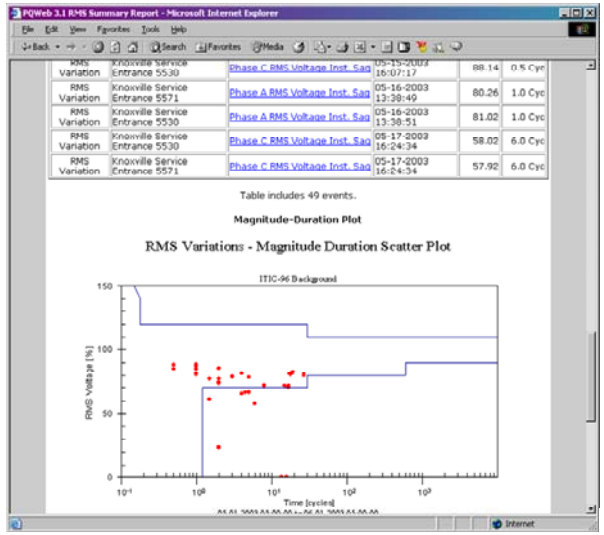












Thank You!

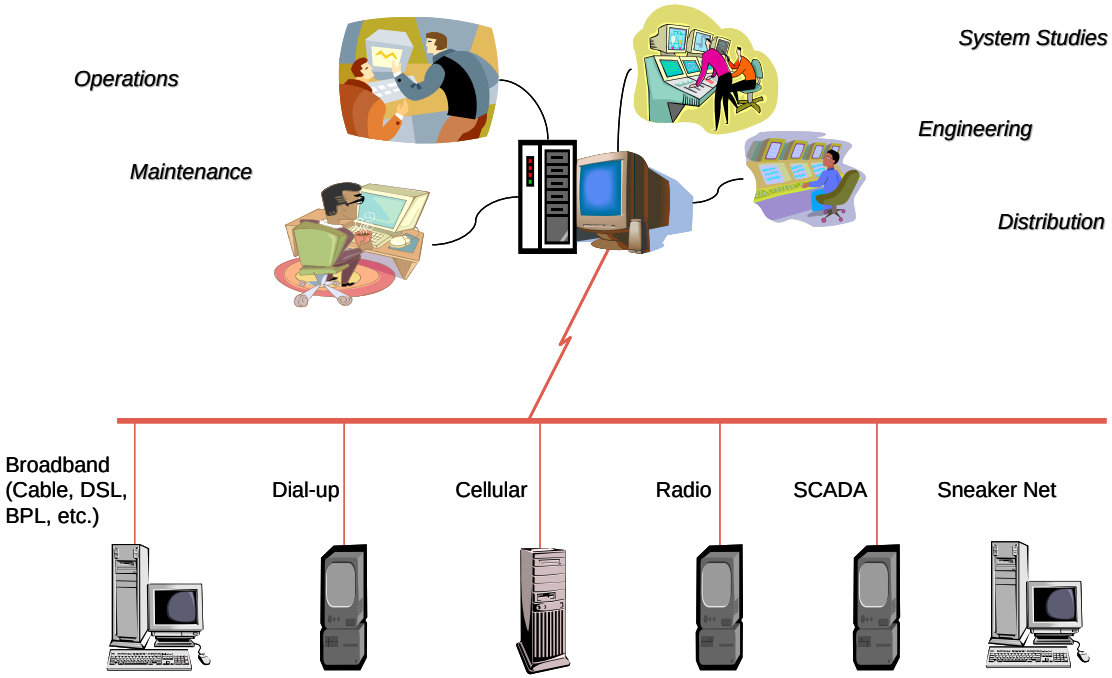
Mark McGranaghan
EPRI Solutions
942 Corridor Park Blvd
Knoxville, TN 37932
865-218-8029
mmcgranaghan@eprisolutions.com

Summaries of Partner Utility Applications

- The following slides summarize important systems and activities for the partner utilities
- Roles in the DFA Development
- Monitoring systems for contributions to the Disturbance Library
- Examples of existing advanced monitoring applications, such as fault location

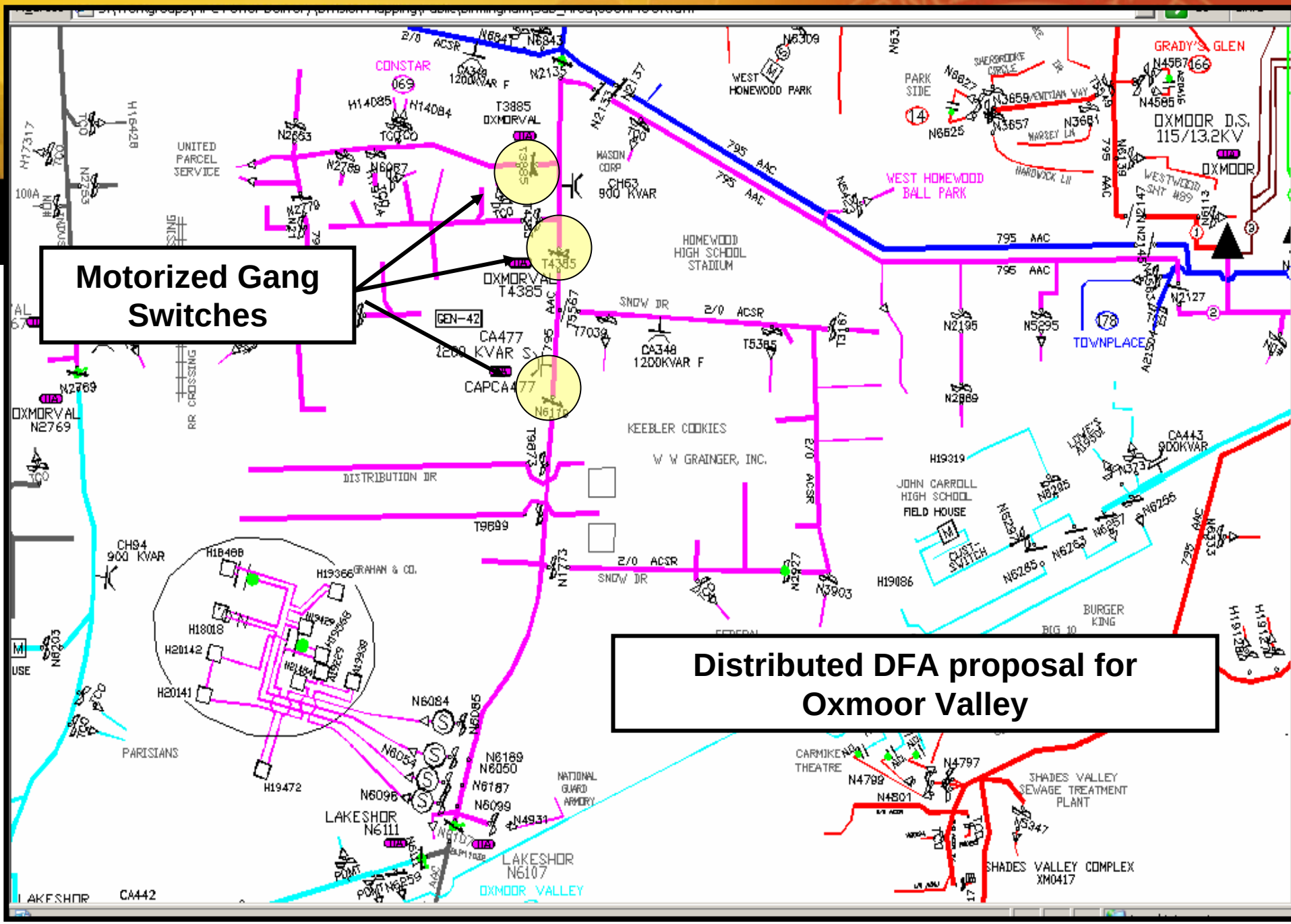
TXU Electric Delivery

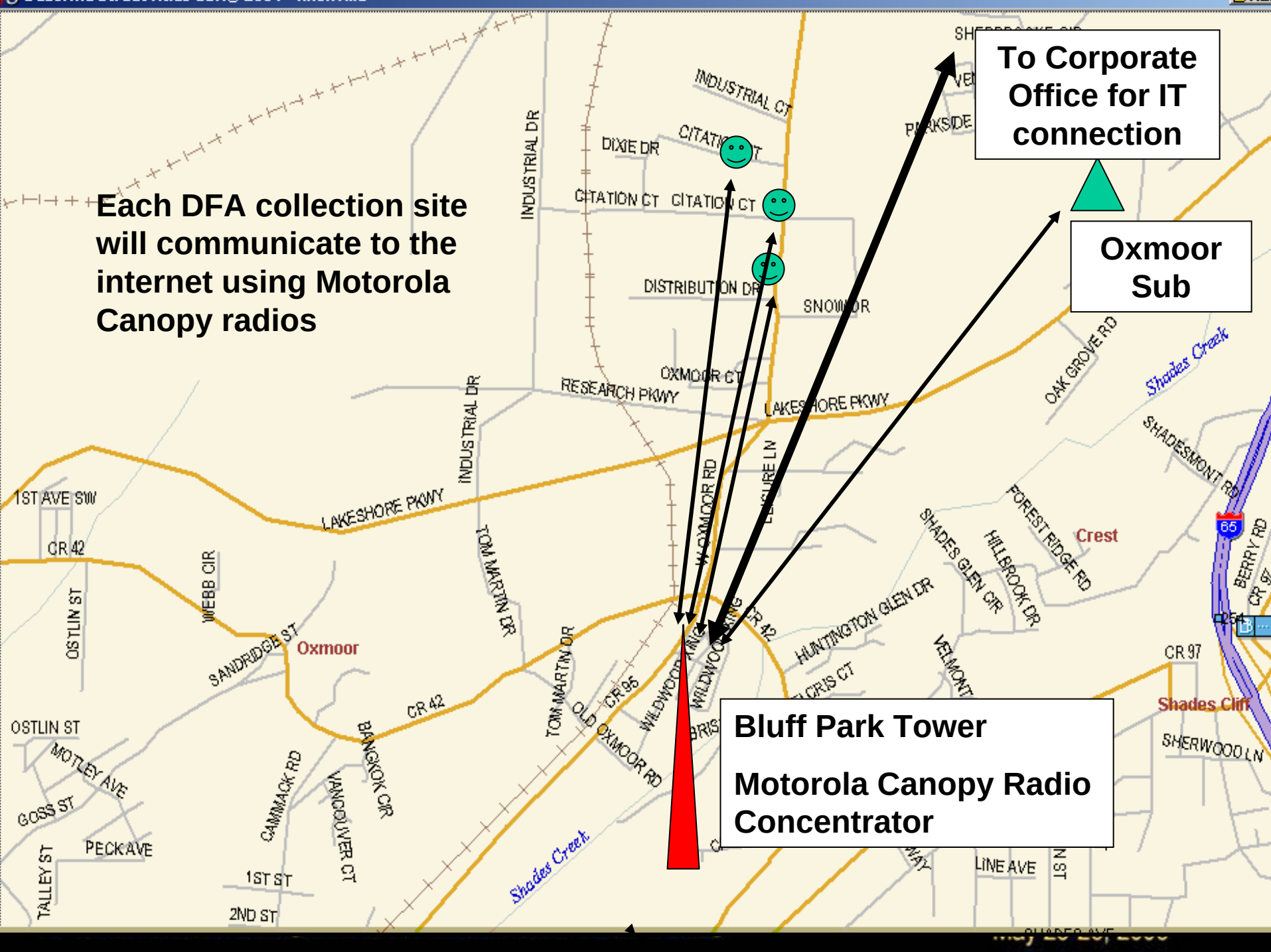
- Form, manage, and lead the focus group for DFA product development.
- Pilot installation site for the substation-based DFA platform.



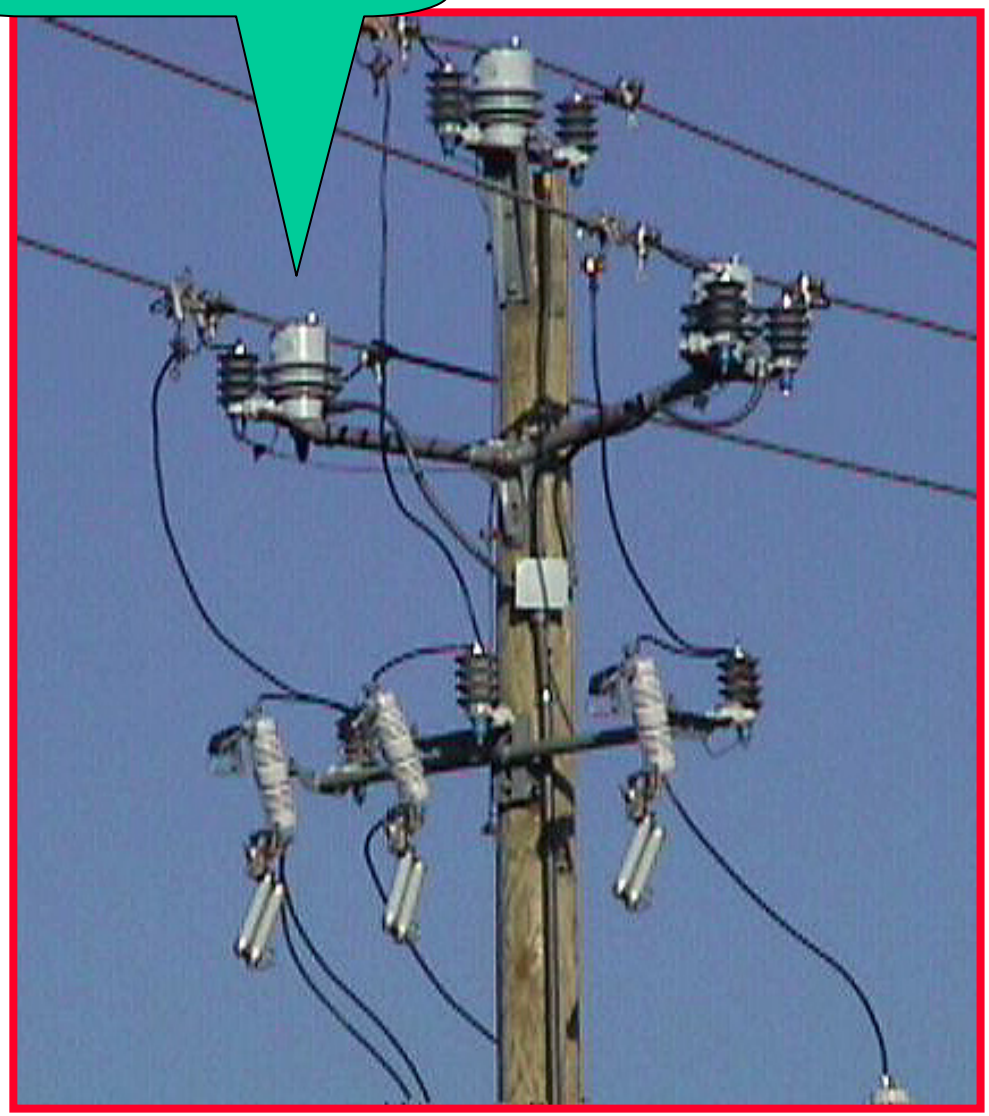
Southern Company

- Pilot installation site for the distributed DFA platform.
  - Motor Operated Switches
  - Electronic Reclosers
  - Switched Capacitors
  - Regulators with Electronic Controls
- Southern Company power quality monitoring system
  - Quad IV Meters
  - Schweitzer relays
  - PQ Monitors


Motorized Gang Switches
Distributed DFA proposal for Oxmoor Valley
CONSTAR
069
T3885
OXMORVAL
T4385
CAPCA477
GEN-42
CA477
1200 KVAR S
CA348
1200KVAR F
CA443
1200KVAR
CH94
900 KVAR
CH63
900 KVAR
WEST HOMEWOOD PARK
WEST HOMEWOOD BALL PARK
HOMEWOOD HIGH SCHOOL STADIUM
OXMOOR D.S.
115/13.2KV
OXMOOR
GRADY'S GLEN
TOWNPLACE
UNITED PARCEL SERVICE
MASON CORP
KEEBLER COOKIES
W W GRAINGER, INC.
JOHN CARROLL HIGH SCHOOL FIELD HOUSE
GRAHAM & CO.
PARISIANS
CARMIKE THEATRE
BURGER KING
SHADES VALLEY SEWAGE TREATMENT PLANT
SHADES VALLEY COMPLEX
XM0417
NATIONAL GUARD ARMORY
LAKESHOR
N6111
LAKESHOR
N6107
OXMOOR VALLEY
CA442
DISTRIBUTION DR
SNOW DR
RR CROSSING
795 AAC
2/0 ACSR


Each DFA collection site will communicate to the internet using Motorola Canopy radios
To Corporate Office for IT connection
Oxmoor Sub
Bluff Park Tower
Motorola Canopy Radio Concentrator
INDUSTRIAL CT
INDUSTRIAL DR
DIXIE DR
CITATION CT
DISTRIBUTION DR
OXMOOR CT
RESEARCH PKWY
LAKESHORE PKWY
OAK GROVE RD
Shades Creek
SHADESMONT RD
1ST AVE SW
CR 42
WEBB CIR
OSTLIN ST
SANDRIDGE ST
Oxmoor
TOM MARTIN DR
WILDWOOD RD
OLD OXMOOR RD
CR 96
HUNTINGTON GLEN DR
SHADES GLEN CIR
HILLBROOK DR
FOREST RIDGE RD
Crest
65
BERRY RD
CR 97
Shades Cliff
SHERWOOD LN
MOTLEY AVE
GOSS ST
PECK AVE
TALLEY ST
CAMMACK RD
VANCOUVER CT
BANGKOK CIR
1ST ST
2ND ST
LINE AVE

Voltage/Current Sensors



Each installation will have 3 – voltage current sensors that will feed into the existing RTU and the new DFA hardware.

Each site will continue to report SCADA data to APCO control center plus it will have the additional ability to report information via the internet connection to Texas A&M.

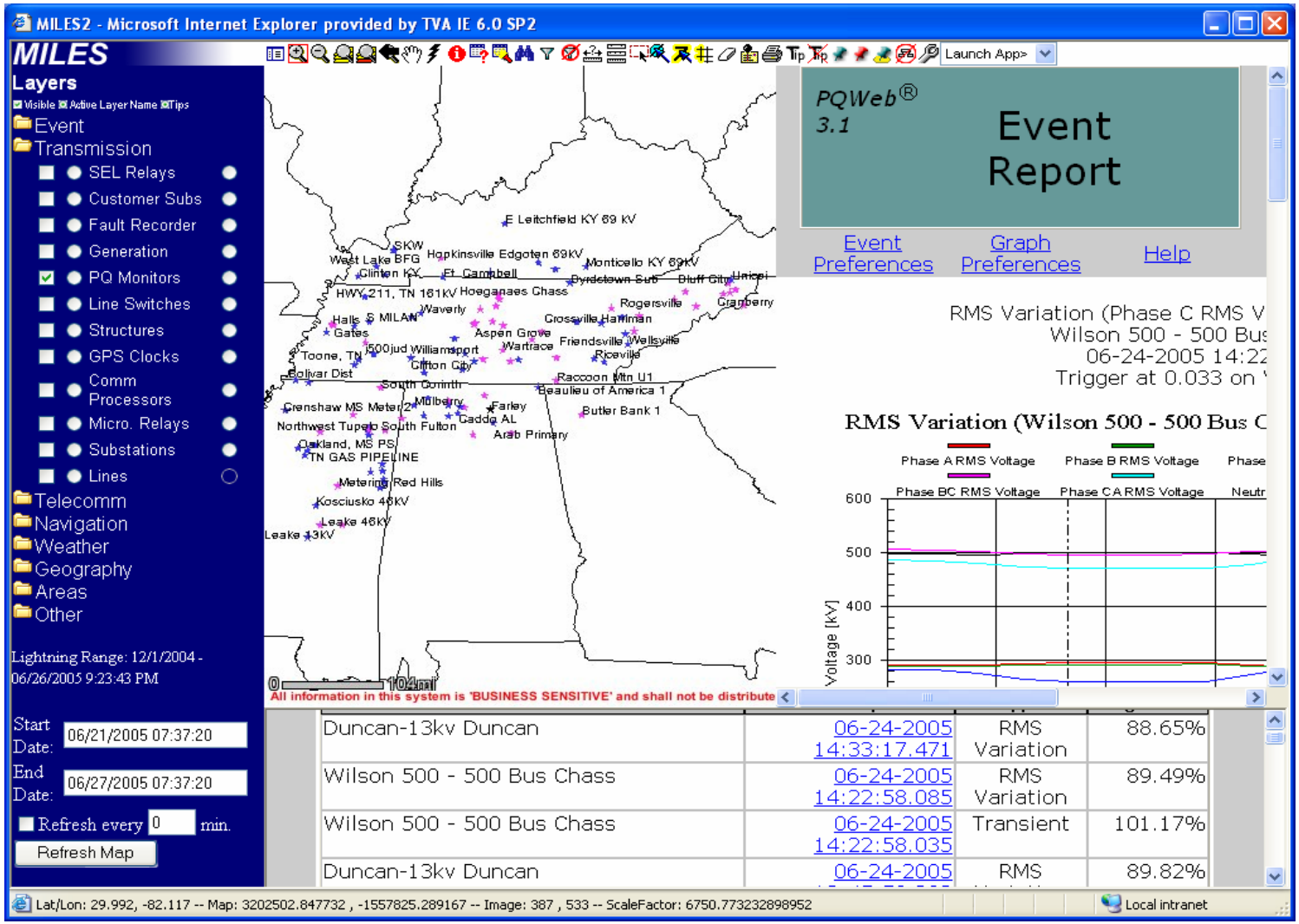
American Electric Power (AEP)

- Extensive substation-based power quality monitoring system using Dranetz-BMI PQNodes
- Monitoring at custom power park to evaluate static series compensator device (Dynamic Voltage Restorer) and static transfer switch
- Integration of data from General Electric KV2 meters for widespread information about disturbances.
  - Has developed an automatic converter from GE HHF File format to IEEE PQDIF format

Tennessee Valley Authority (TVA)

- Extensive power quality monitoring system (over 250 monitoring locations).
- These monitoring locations include distribution substations of TVA distributors.
- TVA also participates in the DFA project through one of their distributors.
- Integration of data from Schweitzer relays and Fault Recorders.
- Testing fault location functionality for transmission line faults

Web-based access to monitoring system - MILES



Consolidated Edison

- Extensive power quality monitoring system that has focused primarily on the secondary system of their underground network. More recent efforts have focused on substation monitoring and possible applications of the monitoring system that can improve operations.
- The substation monitoring efforts are being expanded with fault location algorithms to reduce the time required to repair failed cables.
- The disturbances provided by Con Edison for the library will be extremely valuable because they will represent a different type of system than those of the other partner utilities.

Locating faults on the underground feeders

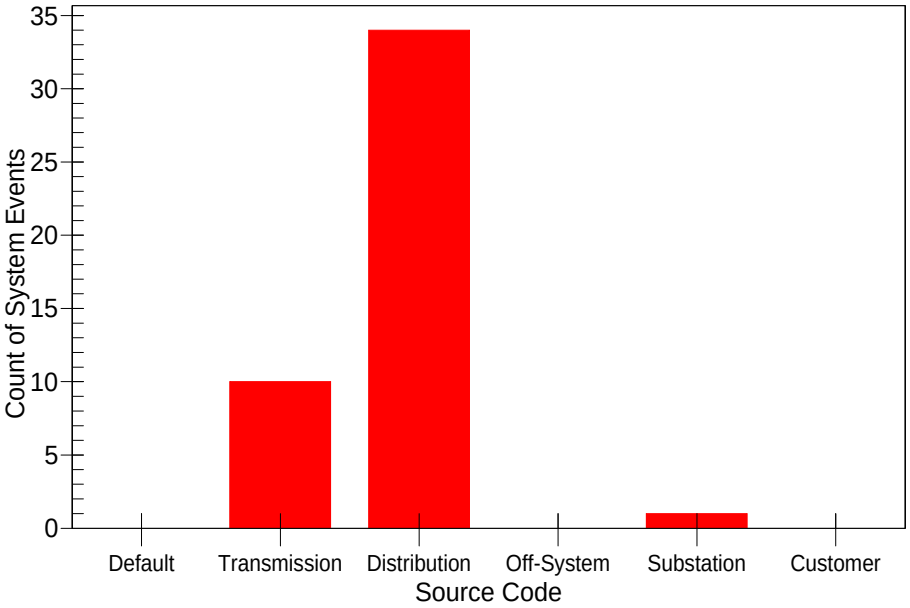
- Reduce fault locating time and costs
- Direct field crews more efficiently
- Maintain network reliability
- After feeder open-autos (OA) PQ software automatically calculates a feeder fault location

San Diego Gas & Electric (SDG&E)

- Extensive substation power quality monitoring system (over 40 substations and customer locations).
- Track cause, source, and description of every sag below 0.90 per unit.
- Project to implement fault location as part of the PQView-based data management system.
- Web-based access (PQWeb) to system for use throughout the company.
- Adding interfaces to other intelligent substation devices to enhance the system.

System Events by Source Code

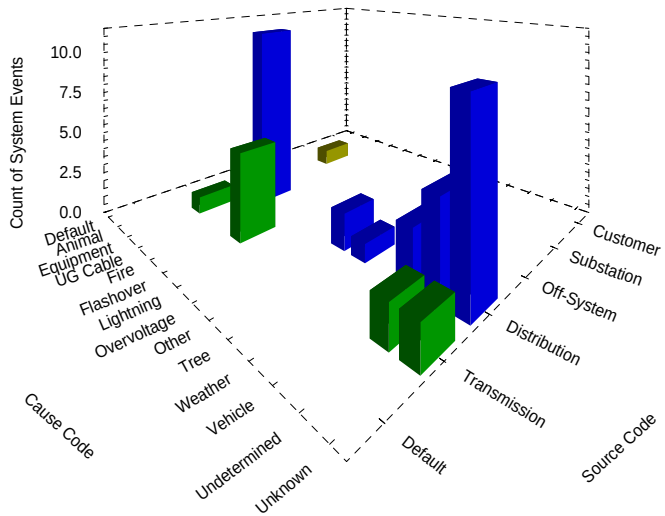
All Sites, From 1/1/2002 to 1/1/2003



Electrotek/EPRI Total System Events: 45 PQView®

System Events by Cause versus Source

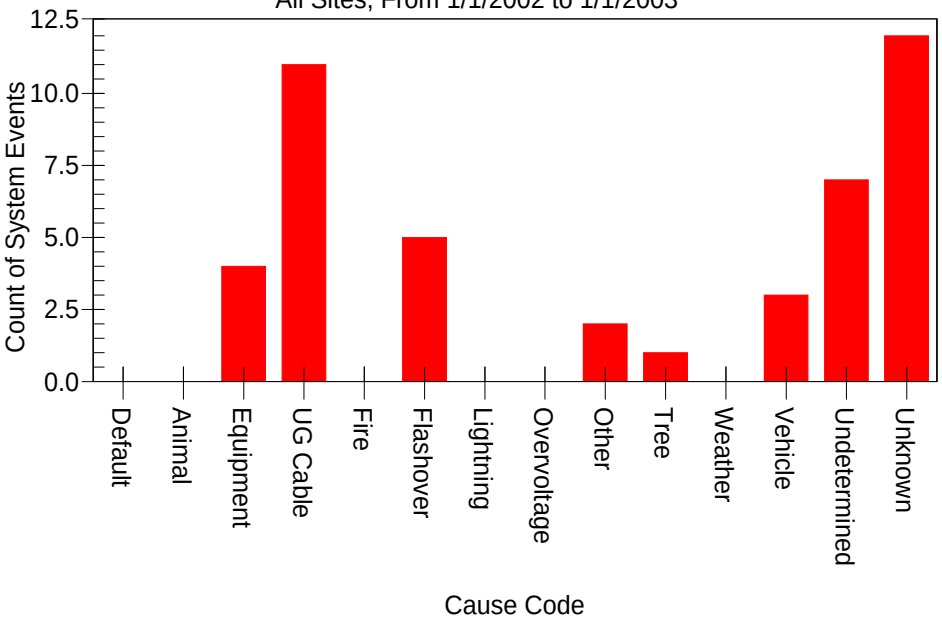
All Sites, From 1/1/2002 to 1/1/2003



Electrotek/EPRI Total System Events: 45 PQView®

System Events by Cause Code

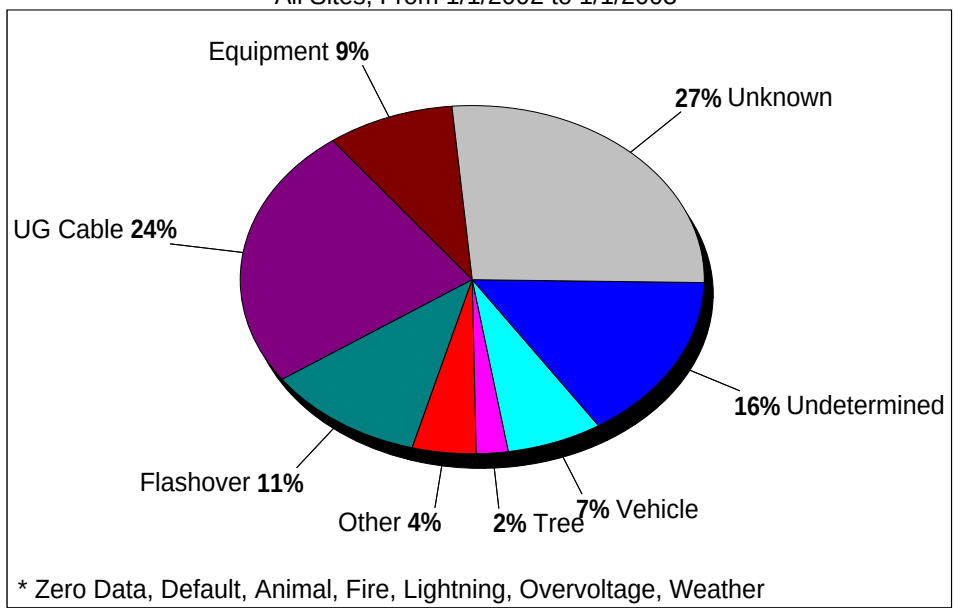
All Sites, From 1/1/2002 to 1/1/2003



Electrotek/EPRI Total System Events: 45 PQView®

System Events by Cause Code

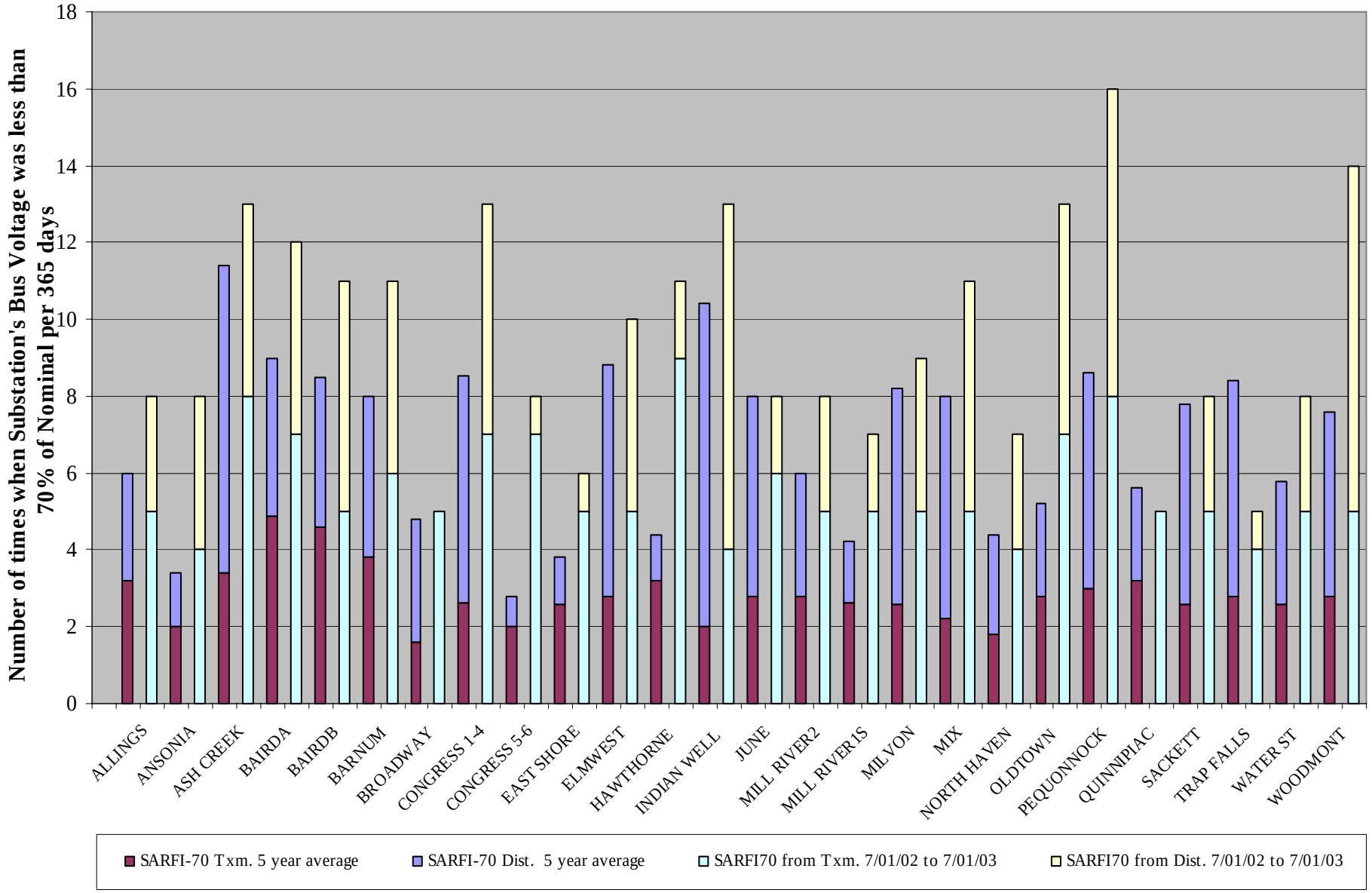
All Sites, From 1/1/2002 to 1/1/2003



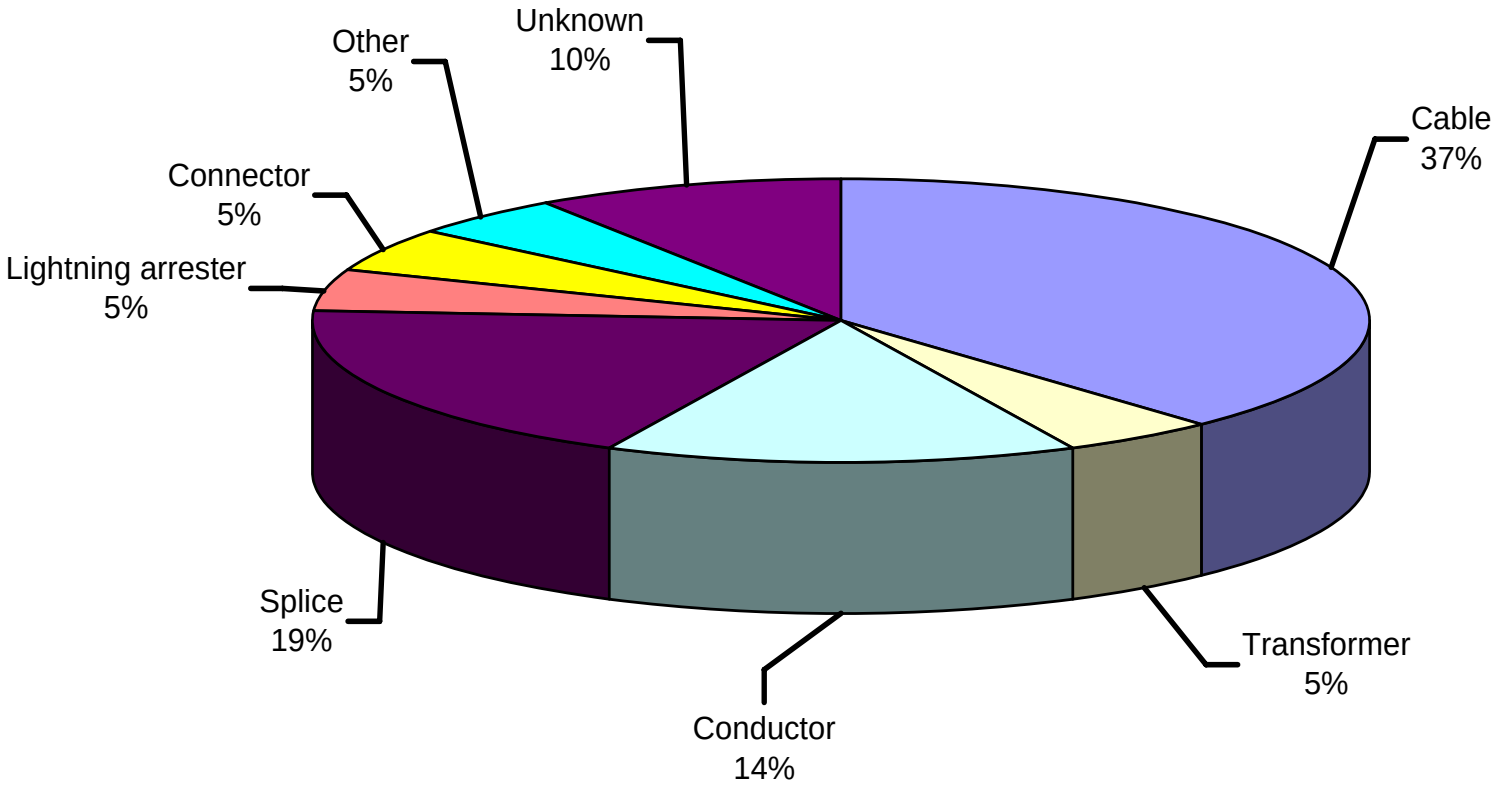
Electrotek/EPRI Total System Events: 45 PQView®

United Illuminating (UI)

- Power quality monitoring at all distribution substations.
- The system has already been structured so that operators have direct access to the data (via the intranet) to help locate faults and determine the causes of disturbances.
- UI is upgrading the monitoring system at all substations with network connectivity to improve access to data in real time.
- Monitoring on individual feeder circuits will be evaluated to allow evaluation of a wider range of intelligent algorithms.


Comparison of UI Substation's SARFI 70 performance of the last 12 months vs. their 5 year average
Number of times when Substation's Bus Voltage was less than 70% of Nominal per 365 days
0
2
4
6
8
10
12
14
16
18
ALLINGS
ANSONIA
ASH CREEK
BAIRDA
BAIRDB
BARNUM
BROADWAY
CONGRESS 1-4
CONGRESS 5-6
EAST SHORE
ELMWEST
HAWTHORNE
INDIAN WELL
JUNE
MILL RIVER2
MILL RIVER1S
MILVON
MIX
NORTH HAVEN
OLDTOWN
PEQUONNOCK
QUINNIPIAC
SACKETT
TRAP FALLS
WATER ST
WOODMONT
SARFI-70 Txm. 5 year average
SARFI-70 Dist. 5 year average
SARFI70 from Txm. 7/01/02 to 7/01/03
SARFI70 from Dist. 7/01/02 to 7/01/03

Equipment Failures During 2nd. Quarter of 2003 - By Category

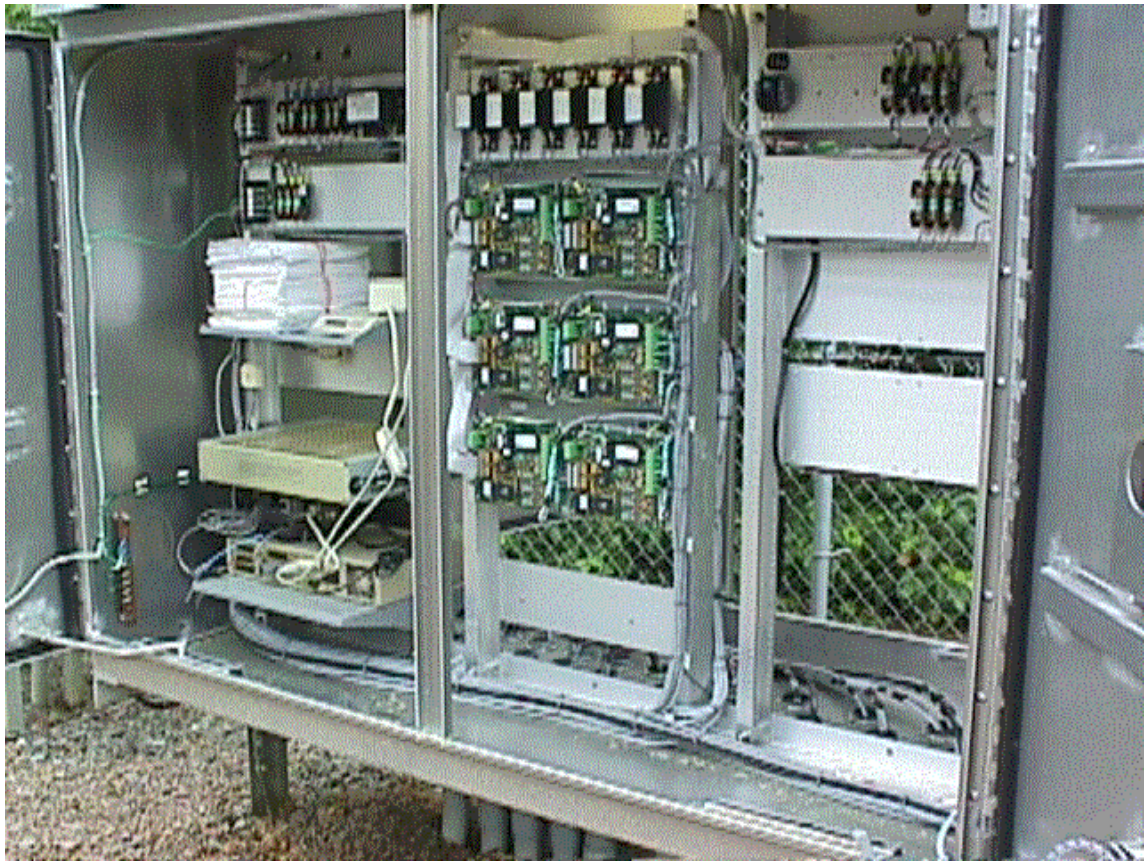


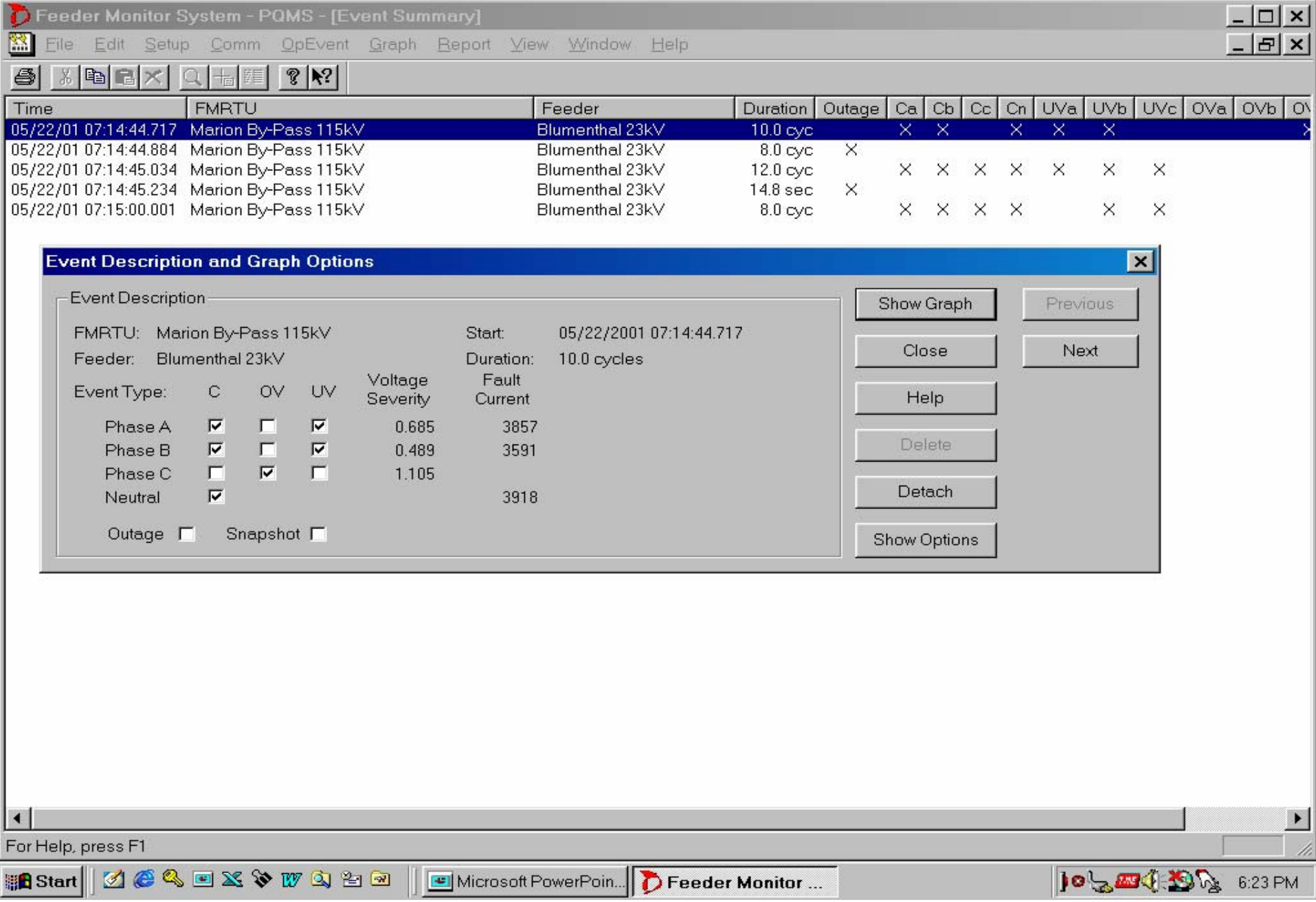
Progress Energy Carolina

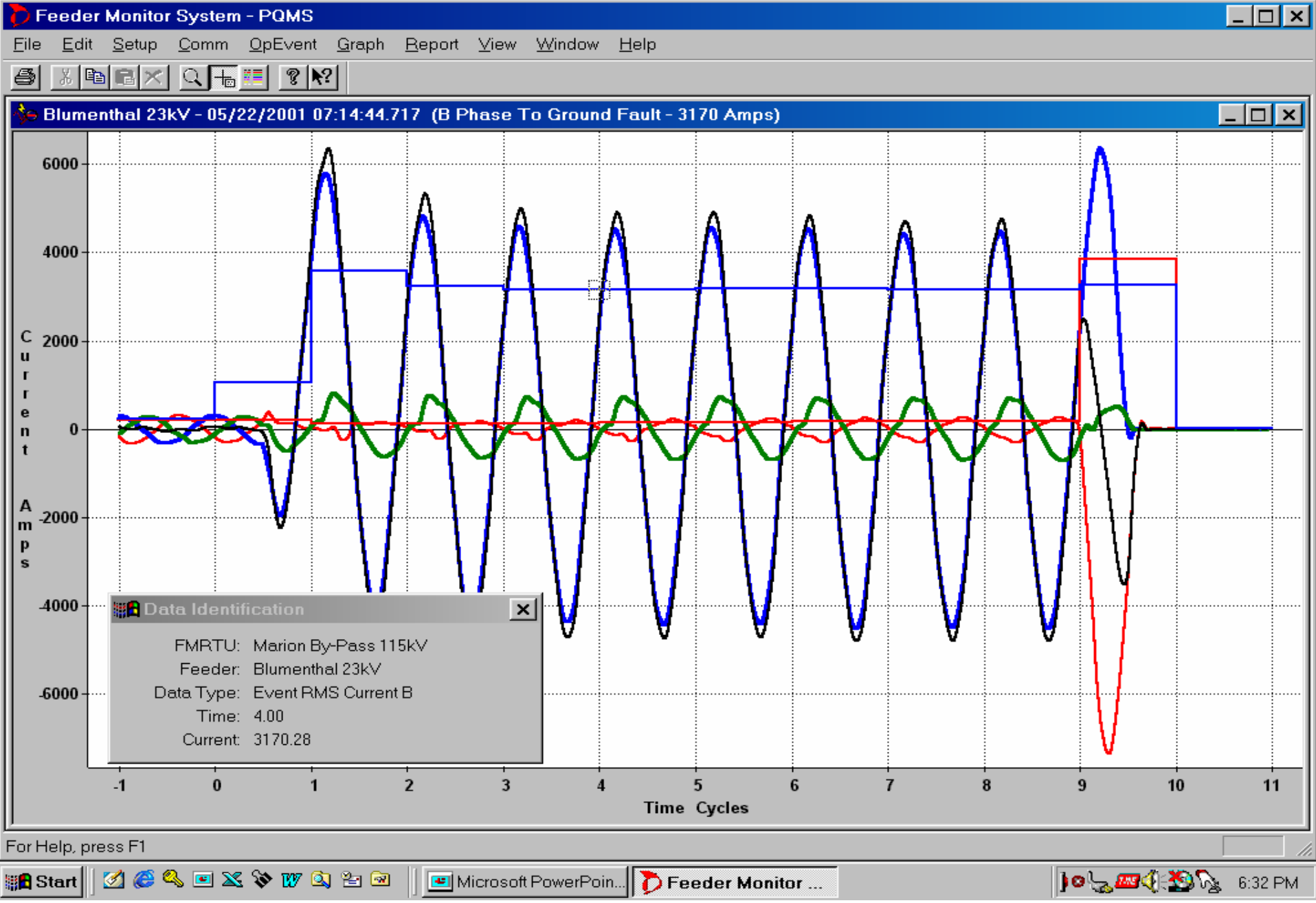
- Already applying automated fault location technology that is integrated with a complete feeder monitoring system.
- Every feeder is monitored with RTUs that provide both voltage and current information for every fault event (including many incipient faults).
  - Over 1000 feeder circuits
  - System operating since 1999
  - Over 1.5 million events
- Automated fault location that is integrated with GIS and electrical system data.

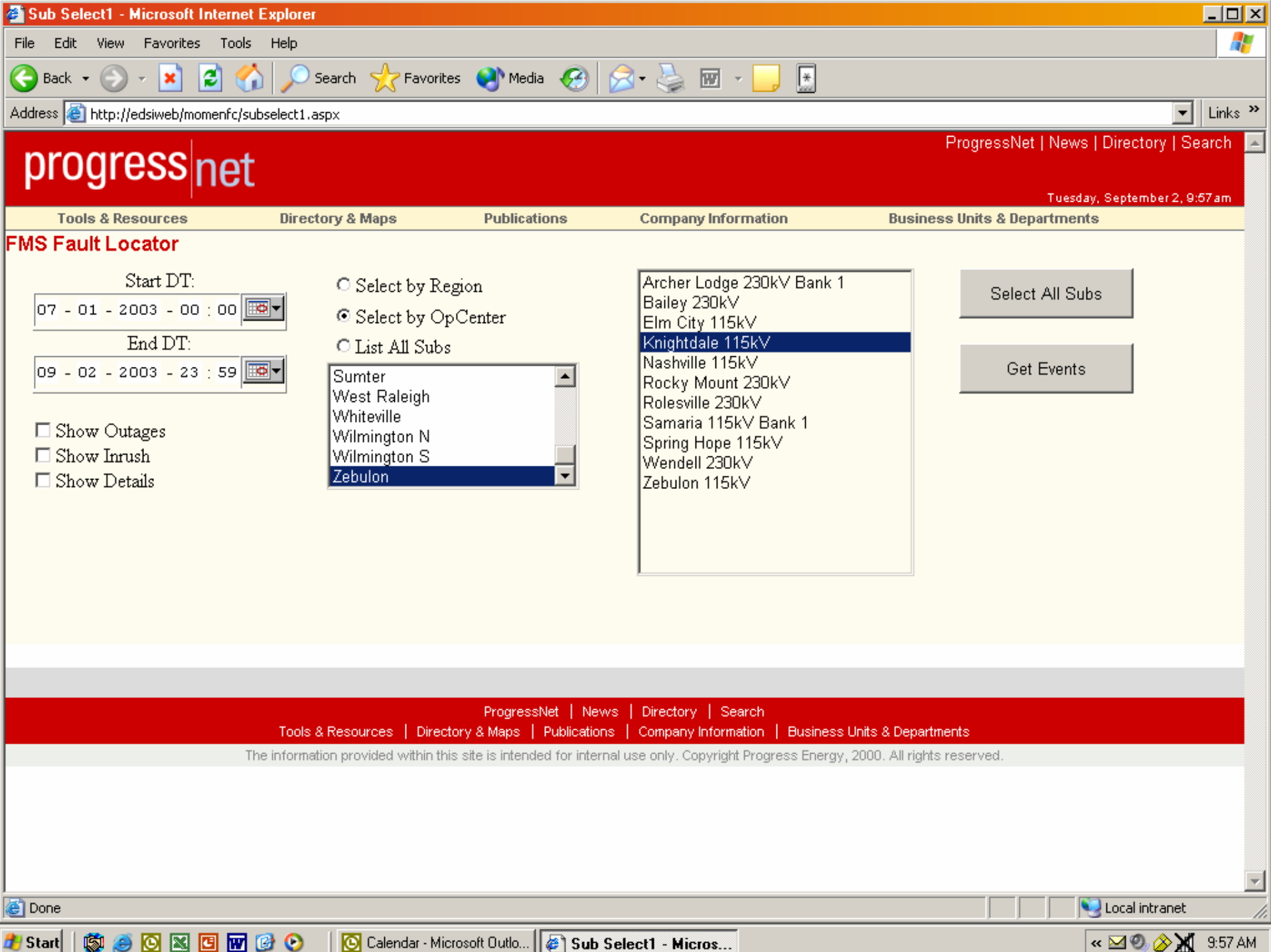
Monitoring Equipment

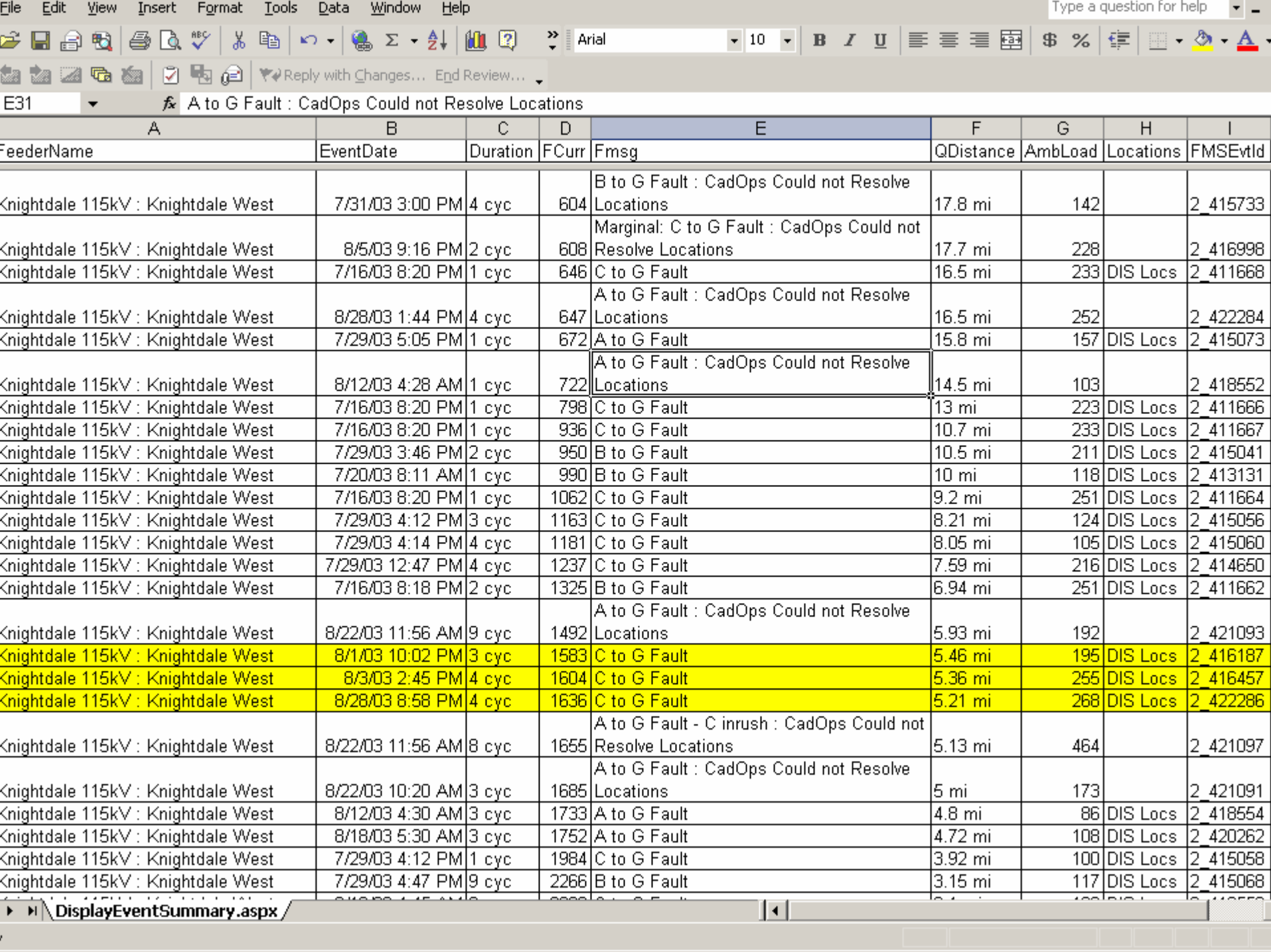
Substation RTU




Feeder Monitor System - PQMS - [Event Summary]
File Edit Setup Comm OpEvent Graph Report View Window Help
Time FMRTU Feeder Duration Outage Ca Cb Cc Cn UVa UVb UVc OVa OVb
05/22/01 07:14:44.717 Marion By-Pass 115kV Blumenthal 23kV 10.0 cyc
05/22/01 07:14:44.884 Marion By-Pass 115kV Blumenthal 23kV 8.0 cyc
05/22/01 07:14:45.034 Marion By-Pass 115kV Blumenthal 23kV 12.0 cyc
05/22/01 07:14:45.234 Marion By-Pass 115kV Blumenthal 23kV 14.8 sec
05/22/01 07:15:00.001 Marion By-Pass 115kV Blumenthal 23kV 8.0 cyc
Event Description and Graph Options
Event Description
FMRTU: Marion By-Pass 115kV
Feeder: Blumenthal 23kV
Start: 05/22/2001 07:14:44.717
Duration: 10.0 cycles
Event Type: C OV UV Voltage Severity Fault Current
Phase A 0.685 3857
Phase B 0.489 3591
Phase C 1.105
Neutral 3918
Outage Snapshot
Show Graph
Previous
Close
Next
Help
Delete
Detach
Show Options
For Help, press F1
Start
Microsoft PowerPoin...
Feeder Monitor ...
6:23 PM


Feeder Monitor System - PQMS
File Edit Setup Comm OpEvent Graph Report View Window Help
Blumenthal 23kV - 05/22/2001 07:14:44.717 (B Phase To Ground Fault - 3170 Amps)
6000
4000
2000
0
-2000
-4000
-6000
Current Amps
-1 0 1 2 3 4 5 6 7 8 9 10 11
Time Cycles
Data Identification
FMRTU: Marion By-Pass 115kV
Feeder: Blumenthal 23kV
Data Type: Event RMS Current B
Time: 4.00
Current: 3170.28
For Help, press F1
Start
Microsoft PowerPoin...
Feeder Monitor ...
6:32 PM


Sub Select1 - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites Media
Address http://edsiweb/momenfc/subselect1.aspx
Links
progress net
ProgressNet | News | Directory | Search
Tuesday, September 2, 9:57 am
Tools & Resources
Directory & Maps
Publications
Company Information
Business Units & Departments
FMS Fault Locator
Start DT:
07 - 01 - 2003 - 00 : 00
End DT:
09 - 02 - 2003 - 23 : 59
Show Outages
Show Inrush
Show Details
Select by Region
Select by OpCenter
List All Subs
Sumter
West Raleigh
Whiteville
Wilmington N
Wilmington S
Zebulon
Archer Lodge 230kV Bank 1
Bailey 230kV
Elm City 115kV
Knightdale 115kV
Nashville 115kV
Rocky Mount 230kV
Rolesville 230kV
Samaria 115kV Bank 1
Spring Hope 115kV
Wendell 230kV
Zebulon 115kV
Select All Subs
Get Events
ProgressNet | News | Directory | Search
Tools & Resources | Directory & Maps | Publications | Company Information | Business Units & Departments
The information provided within this site is intended for internal use only. Copyright Progress Energy, 2000. All rights reserved.
Done
Local intranet
Start
Calendar - Microsoft Outlo...
Sub Select1 - Micros...
9:57 AM



File Edit View Insert Format Tools Data Window Help

Type a question for help

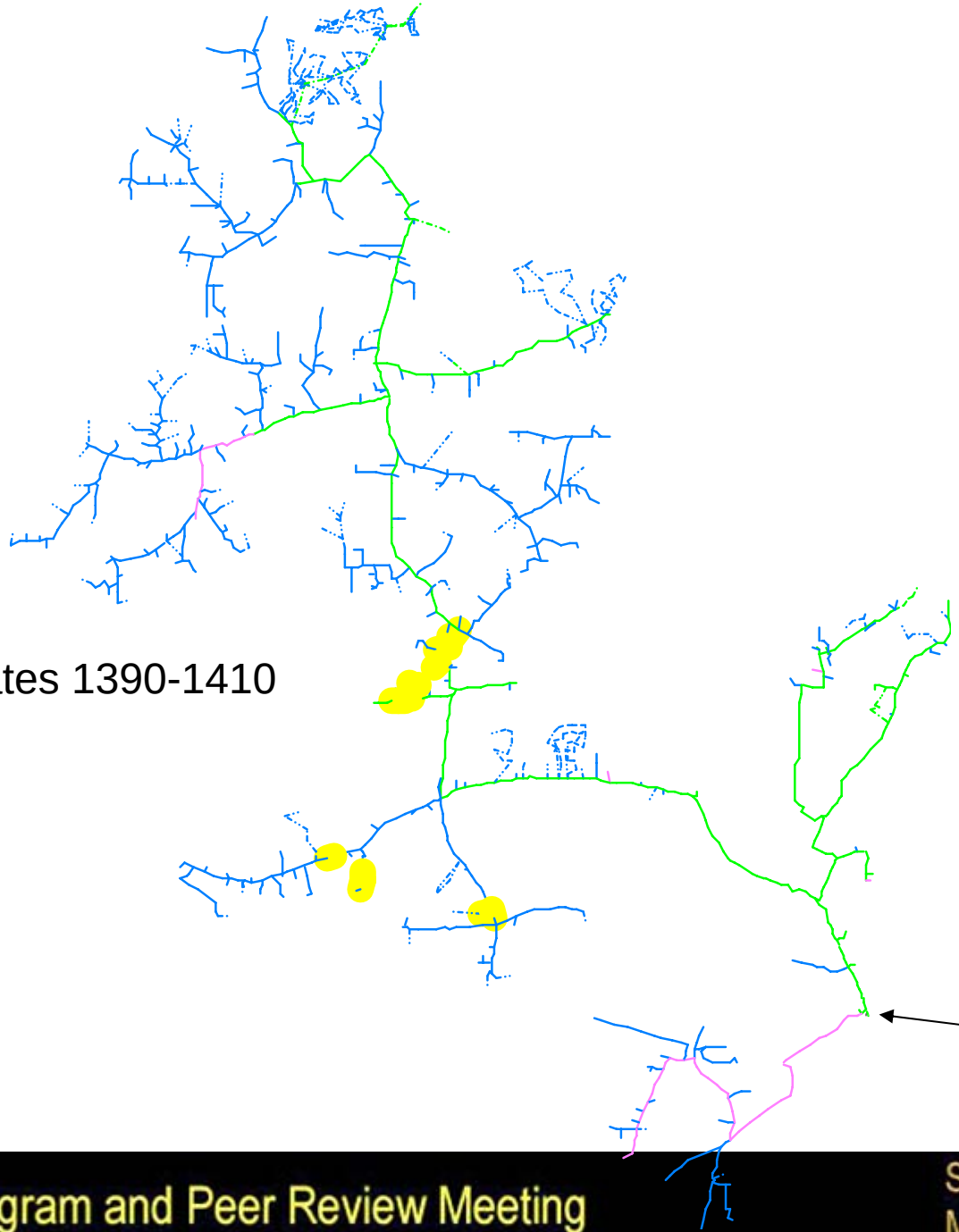
Arial 10

Reply with Changes... End Review...

E31 A to G Fault : CadOps Could not Resolve Locations

	A	B	C	D	E	F	G	H	I
	FeederName	EventDate	Duration	FCurr	Fmsg	QDistance	AmbLoad	Locations	FMSEvtId
	Knightdale 115kV : Knightdale West	7/31/03 3:00 PM	4 cyc	604	B to G Fault : CadOps Could not Resolve Locations	17.8 mi	142		2_415733
	Knightdale 115kV : Knightdale West	8/5/03 9:16 PM	2 cyc	608	Marginal: C to G Fault : CadOps Could not Resolve Locations	17.7 mi	228		2_416998
	Knightdale 115kV : Knightdale West	7/16/03 8:20 PM	1 cyc	646	C to G Fault	16.5 mi	233	DIS Locs	2_411668
	Knightdale 115kV : Knightdale West	8/28/03 1:44 PM	4 cyc	647	A to G Fault : CadOps Could not Resolve Locations	16.5 mi	252		2_422284
	Knightdale 115kV : Knightdale West	7/29/03 5:05 PM	1 cyc	672	A to G Fault	15.8 mi	157	DIS Locs	2_415073
	Knightdale 115kV : Knightdale West	8/12/03 4:28 AM	1 cyc	722	A to G Fault : CadOps Could not Resolve Locations	14.5 mi	103		2_418552
	Knightdale 115kV : Knightdale West	7/16/03 8:20 PM	1 cyc	798	C to G Fault	13 mi	223	DIS Locs	2_411666
	Knightdale 115kV : Knightdale West	7/16/03 8:20 PM	1 cyc	936	C to G Fault	10.7 mi	233	DIS Locs	2_411667
	Knightdale 115kV : Knightdale West	7/29/03 3:46 PM	2 cyc	950	B to G Fault	10.5 mi	211	DIS Locs	2_415041
	Knightdale 115kV : Knightdale West	7/20/03 8:11 AM	1 cyc	990	B to G Fault	10 mi	118	DIS Locs	2_413131
	Knightdale 115kV : Knightdale West	7/16/03 8:20 PM	1 cyc	1062	C to G Fault	9.2 mi	251	DIS Locs	2_411664
	Knightdale 115kV : Knightdale West	7/29/03 4:12 PM	3 cyc	1163	C to G Fault	8.21 mi	124	DIS Locs	2_415056
	Knightdale 115kV : Knightdale West	7/29/03 4:14 PM	4 cyc	1181	C to G Fault	8.05 mi	105	DIS Locs	2_415060
	Knightdale 115kV : Knightdale West	7/29/03 12:47 PM	4 cyc	1237	C to G Fault	7.59 mi	216	DIS Locs	2_414650
	Knightdale 115kV : Knightdale West	7/16/03 8:18 PM	2 cyc	1325	B to G Fault	6.94 mi	251	DIS Locs	2_411662
	Knightdale 115kV : Knightdale West	8/22/03 11:56 AM	9 cyc	1492	A to G Fault : CadOps Could not Resolve Locations	5.93 mi	192		2_421093
	Knightdale 115kV : Knightdale West	8/1/03 10:02 PM	3 cyc	1583	C to G Fault	5.46 mi	195	DIS Locs	2_416187
	Knightdale 115kV : Knightdale West	8/3/03 2:45 PM	4 cyc	1604	C to G Fault	5.36 mi	255	DIS Locs	2_416457
	Knightdale 115kV : Knightdale West	8/28/03 8:58 PM	4 cyc	1636	C to G Fault	5.21 mi	268	DIS Locs	2_422286
	Knightdale 115kV : Knightdale West	8/22/03 11:56 AM	8 cyc	1655	A to G Fault - C inrush : CadOps Could not Resolve Locations	5.13 mi	464		2_421097
	Knightdale 115kV : Knightdale West	8/22/03 10:20 AM	3 cyc	1685	A to G Fault : CadOps Could not Resolve Locations	5 mi	173		2_421091
	Knightdale 115kV : Knightdale West	8/12/03 4:30 AM	3 cyc	1733	A to G Fault	4.8 mi	86	DIS Locs	2_418554
	Knightdale 115kV : Knightdale West	8/18/03 5:30 AM	3 cyc	1752	A to G Fault	4.72 mi	108	DIS Locs	2_420262
	Knightdale 115kV : Knightdale West	7/29/03 4:12 PM	1 cyc	1984	C to G Fault	3.92 mi	100	DIS Locs	2_415058
	Knightdale 115kV : Knightdale West	7/29/03 4:47 PM	9 cyc	2266	B to G Fault	3.15 mi	117	DIS Locs	2_415068

DisplayEventSummary.aspx



Yellow indicates 1390-1410
LG Fault

Results of feeder monitoring system and fault locating