

Distribution Fault Locating with PI

Presented by **Cameron D. Sherding**, *Sr. Software Engineer*



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DTE Energy is an Integrated Energy Company

Strong, Stable and Growing Utilities



DTE Electric

- Electric generation and distribution
- 2.1 million customers
- Fully regulated by Michigan Public Service Commission



DTE Gas

- Natural gas distribution
- 1.2 million customers
- Fully regulated by Michigan Public Service Commission

Complementary Non-Utility Businesses



Gas Storage & Pipelines (GSP)

Transport and store natural gas



Power & Industrial Projects (P&I)

Own and operate energy related assets



Energy Trading

Generate economic value and provide strategic benefits

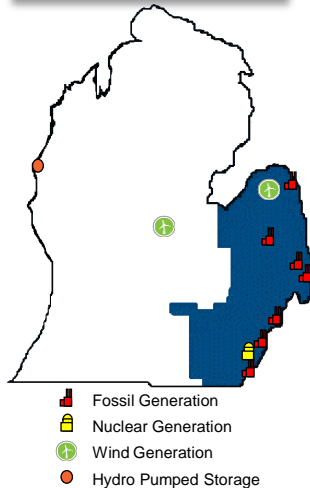
Utility / non-utility earnings mix of 80% / 20% evolves to 70% / 30% by 2018

Profile of DTE Electric

- Twelfth largest US electric utility with 2.1 million customers
- ~\$5 billion in revenue, \$17 billion in assets
- Regulated by the Michigan Public Service Commission (MPSC)
- Contributed nearly 64% of DTE's 2014 earnings

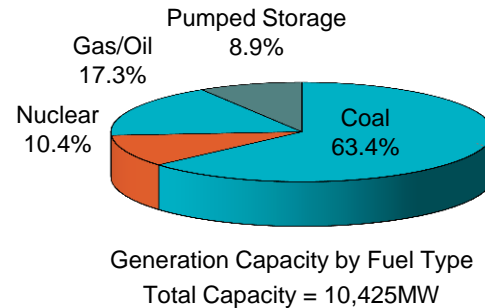
Customer	Count	Load
Residential	1,920k	34%
Commercial	197k	44%
Industrial	1k	22%

Service Territory /
Generating Facilities



Generation
Assets

- 7 Fossil fuel generating plants
- 1 Nuclear power plant
- 1 Hydroelectric pumped storage facility

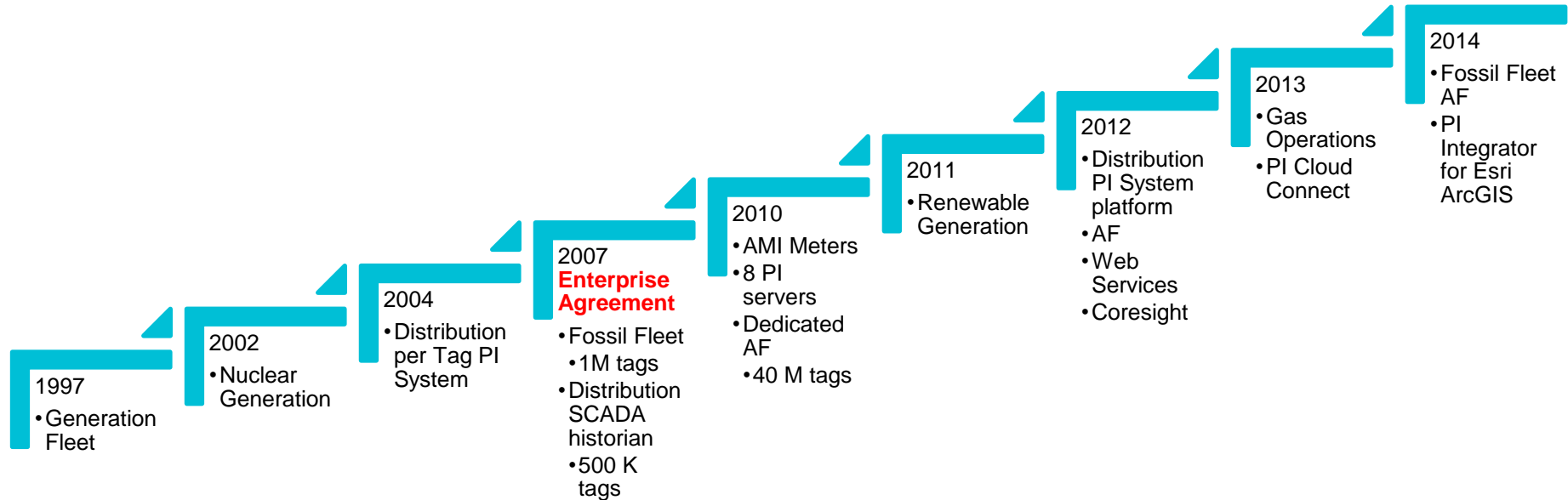


Distribution Assets

- 7,600 square-mile service area
- 671 distribution substations
- 12 Service Centers
- 46,000 miles of power lines

- By 2015, DTE Energy will generate 10 percent of the electricity we provide for our Southeastern Michigan customers from renewable energy sources.
- Initiatives like the Echo-Wind Park will help to produce energy from renewable sources like wind.

History of PI at DTE



Business Challenge

DTE is actively working to reduce customer outage minutes (CAIDI) on the distribution system.

1. Fault Locating

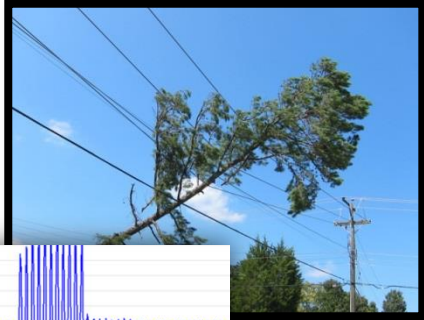
- Many outages are result of faults on the line caused by vegetation, animals, cable or equipment failures
- Quickly locating the source of these faults is critical to minimizing restoration time

2. Low Cost Monitoring

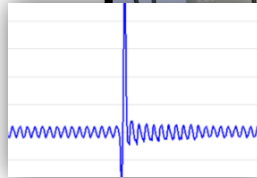
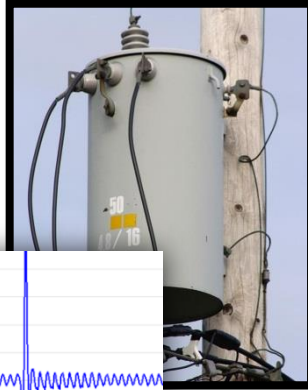
- Aging substations aren't cost-effective to install full SCADA. Basic load data can provide valuable visibility into the system at these locations.

Fault Locating

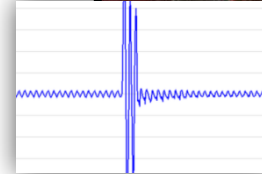
Wire Contact



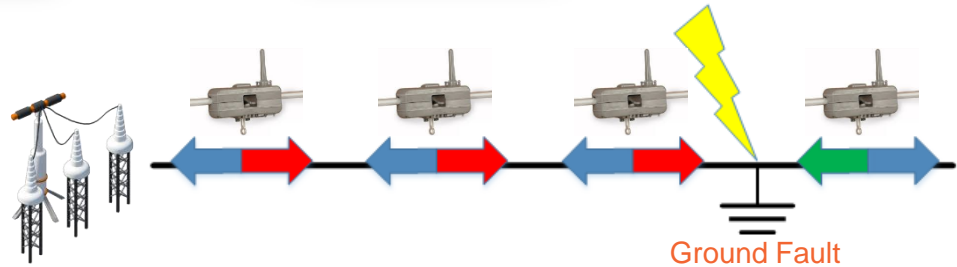
Failing Pole Top Transformer



Failing Underground Cable



Minimizing patrol distances
can improve restore time

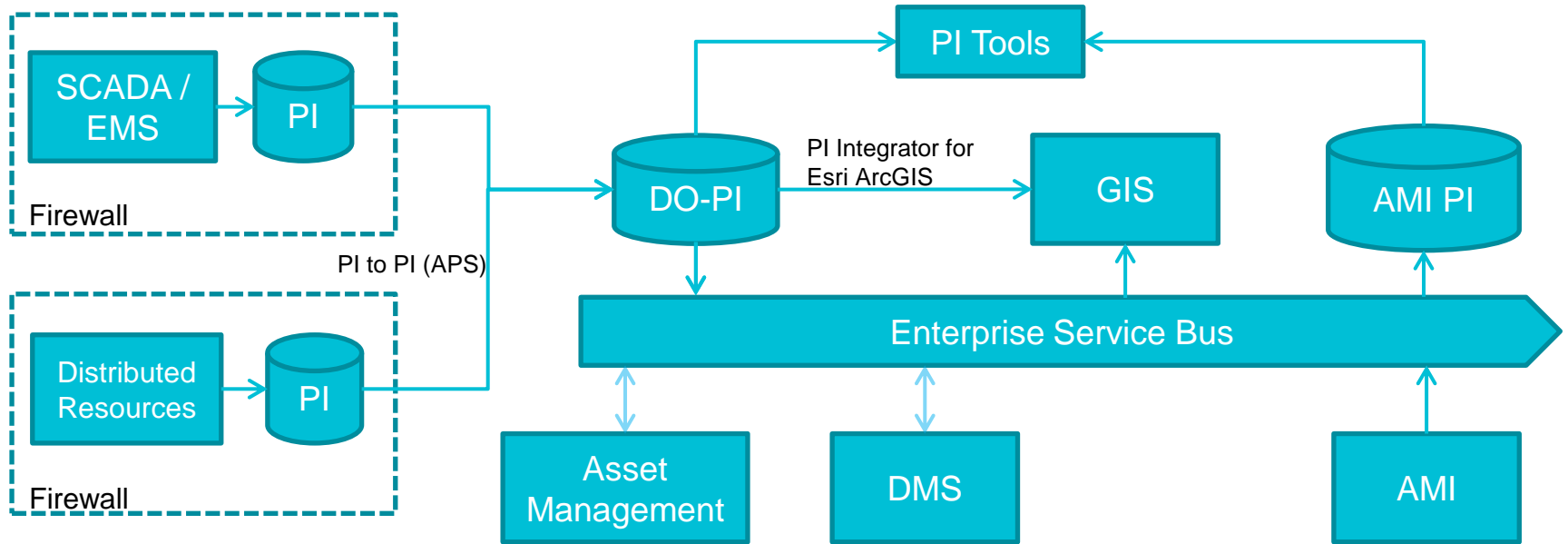


DTE Electric's Distribution Operations

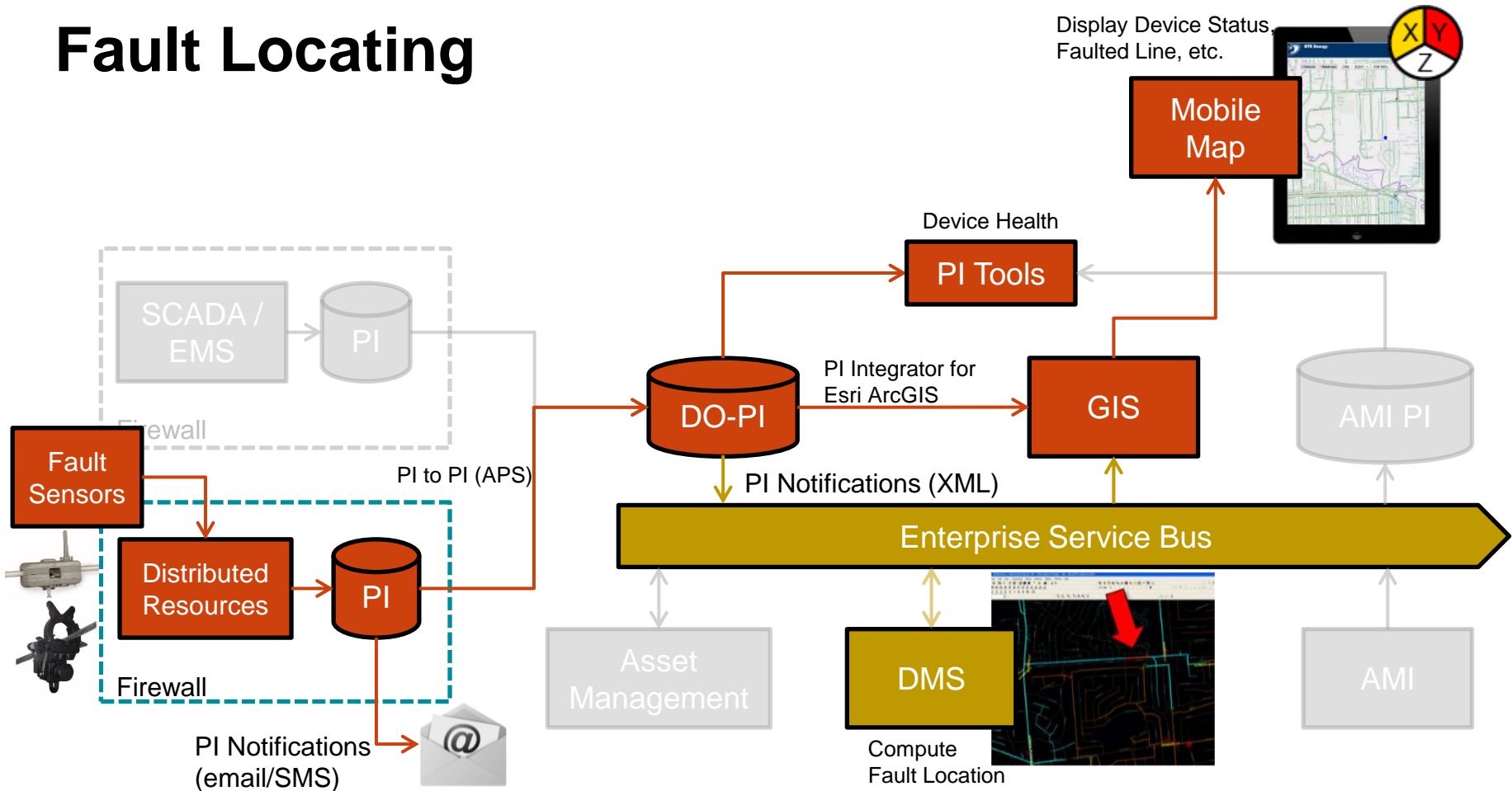
- 450,000+ tags in SCADA historian
- 29,000,000 tags and growing in AMI PI
- PI to PI APS SCADA and DR historian to DO-PI
- PI Server 2014 (HA configuration)
- AF 2014
- Coresight 2014



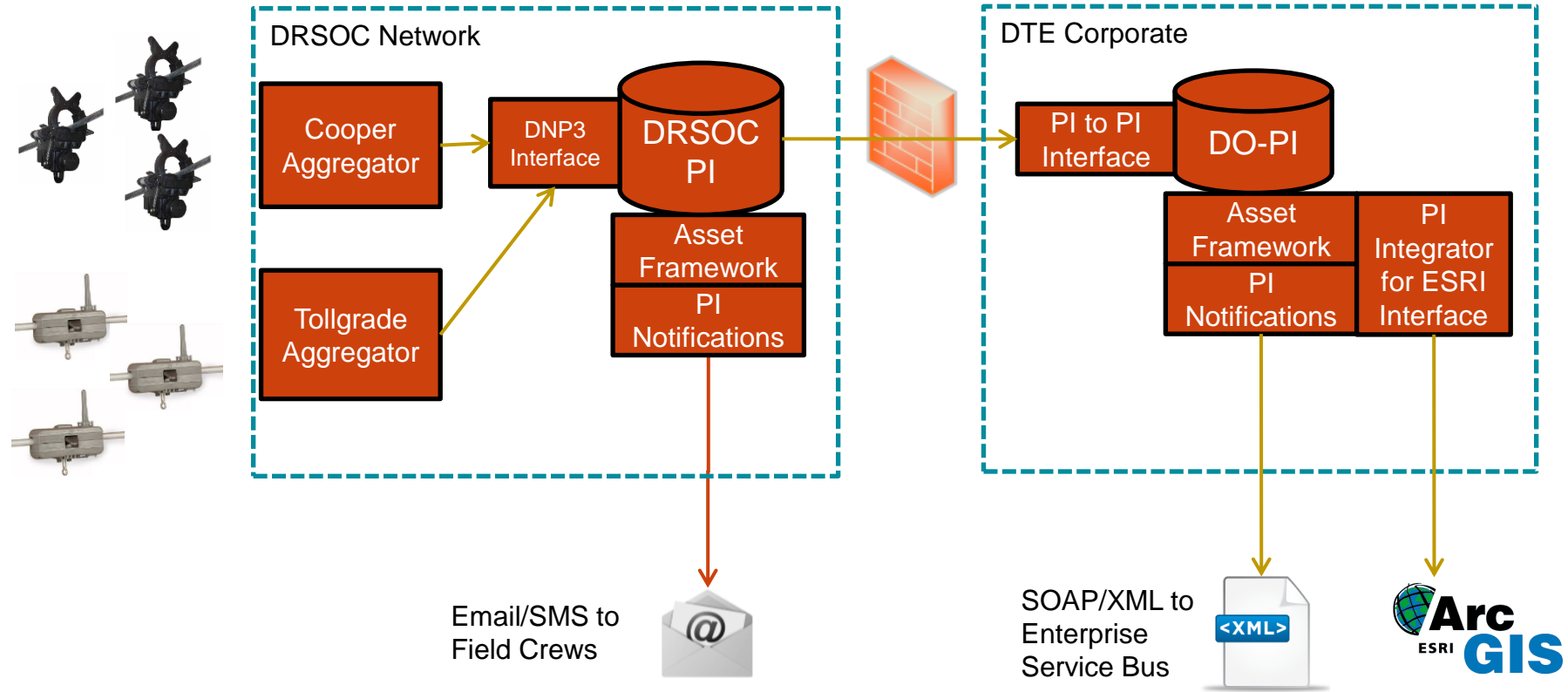
Distribution PI System



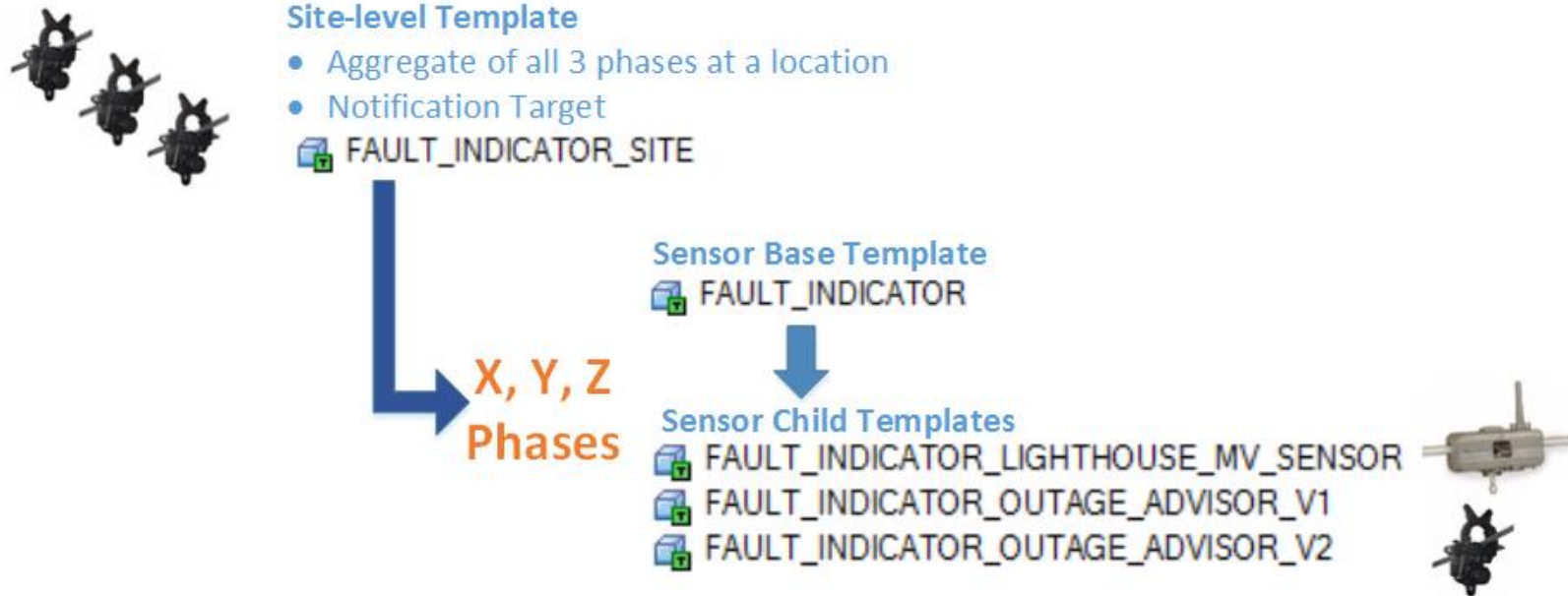
Fault Locating



PI Solution Architecture



Asset Framework









Asset Framework Details








Site-level Template






























FAULT_INDICATOR_SITE

Attribute References:

 Current X	263.5	Default UOM: <None>
 Current Y	245.80000305...	Value Type: Double
 Current Z	220.40000915...	Value: 263.5
 Device ID	MADSN43T	Data Reference: Formula
 DMS_REF	7	
 Fault Current G	0	A=\DEVICES\FAULT INDICATOR\%Element%-XCurrent:[A]

Formulas:

 Fault Current Max	0	Default UOM: <None>
 Fault Current N	0	Value Type: Int32
 Fault Current X	0	Value: 0
 Fault Current Y	0	Data Reference: Formula
 Fault Current Z	0	
 Fault Type	-1	A=Fault Current X;B=Fault Current Y;C=Fault Current Z;[max(max(A,B), C)]
 FEEDERMONITOR	No	

Name	Value
 CIRCUIT	43T
 COMMUNICATIONS	CELLULAR
 Current X	240.19999694824219
 Current Y	225.30000305175781
 Current Z	192.60000610351563
 Device ID	MADSN43T
 DMS_REF	7
 Fault Current G	0
 Fault Current Max	0
 Fault Current N	0
 Fault Current X	0
 Fault Current Y	0
 Fault Current Z	0
 Fault Type	-1
 FEEDERMONITOR	No
 GLNXY	
 Latitude	42.335591
 LOCATION	NB 619
 Longitude	-83.042108
 Momentary Fault Status X	0
 Momentary Fault Status Y	0
 Momentary Fault Status Z	0
 OBJECTID	0
 OHUG	UG
 OUT_HOST_NAME	192.168.247.75
 OUT_PORT_NUM	6161
 Power Status X	0
 Power Status Y	0
 Power Status Z	0



Asset Framework Details

Sensor-level Templates

FAULT_INDICATOR



FAULT_INDICATOR_LIGHTHOUSE_MV_SENSOR

FAULT_INDICATOR_OUTAGE_ADVISOR_V1

FAULT_INDICATOR_OUTAGE_ADVISOR_V2

Building Tag References:

Entering Low Power Mode		Data Reference: PI Point
Entering Normal Mode		Settings...
Fault Current		\\%SERVER%\%@SUBSTATION% %@CIRCUIT PREFIX% %@CIRCUIT% SFI-%@REGION CODE% %@SEQUENCE%- %@PHASE% Fault Current

Entering Normal Mode	True	Settings...
Fault Current	4936 A	\\DOP\ISOFLD DC9010 SFI-H0027-Z Fault Current

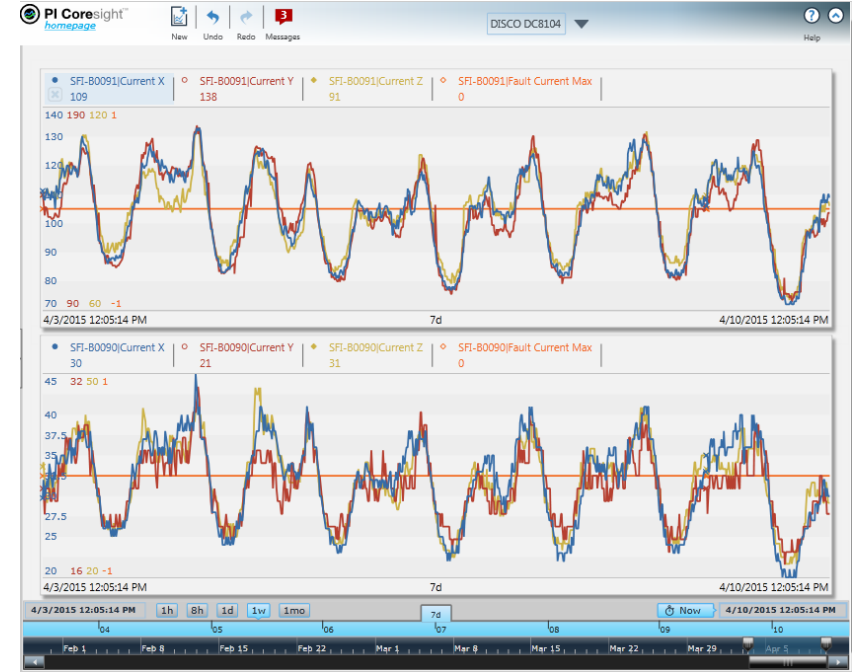
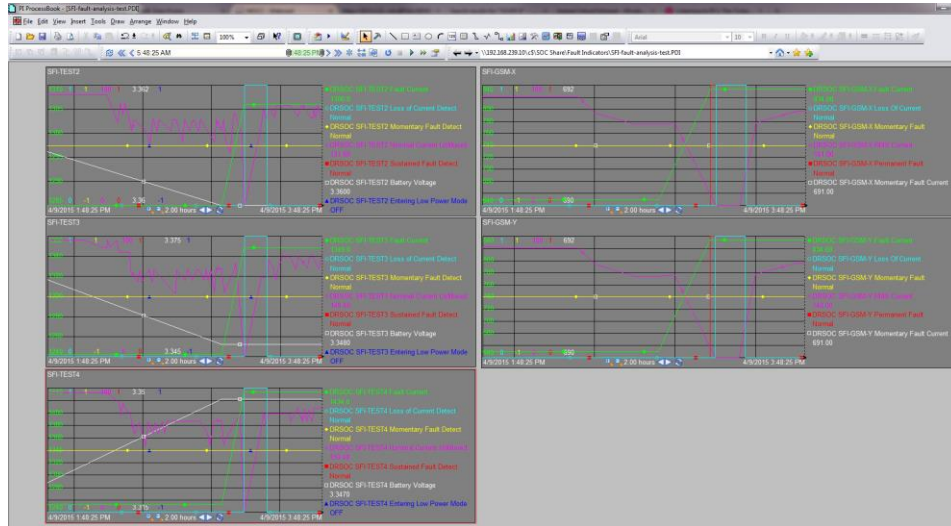
- BREAKER
- BUS
- CABLE POLE
- CAPACITOR
- CIRCUIT
- CIRCUIT SWITCHER
- FAULT INDICATOR

- SFI-A0001-X
- SFI-A0001-Y
- SFI-A0001-Z
- SFI-A0002-X
- SFI-A0002-Y
- SFI-A0002-Z
- SFI-A0003-X
- SFI-A0003-Y
- SFI-A0003-Z
- SFI-A0004-X
- SFI-A0004-Y
- SFI-A0004-Z
- SFI-A0005-X
- SFI-A0005-Y
- SFI-A0005-Z
- SFI-A0006-X
- SFI-A0006-Y
- SFI-A0006-Z
- SFI-A0007-X
- SFI-A0007-Y
- SFI-A0007-Z
- SFI-A0008-X
- SFI-A0008-Y
- SFI-A0008-Z
- SFI-A0009-X
- SFI-A0009-Y
- SFI-A0009-Z
- SFI-A0010-X
- SFI-A0010-Y
- SFI-A0010-Z
- SFI-A0011-X
- SFI-A0011-Y
- SFI-A0011-Z
- SFI-A0012-X

Name	Value
Fault Indication	Normal
Feeder Monitor	No
GLNX	290623
GLNY	335044
GSID	3
Latitude	42.414307
Location	LS W MCNICHOLS 2PE LAHSE
Longitude	-83.256508
Manufacturer	COOPER
Max Current	204 A
Min Current	170 A
Model	OUTAGE_ADVISOR_V1
Momentary Count	1 count
Momentary Count 24hr	0 count
Nominal Current	182 A
ObjectID	5450
OH-UG	OH
Operating Status	OPERATING
Outage Count	5 count
Over Current	Alarm
Phase	X
Phase Number	1
Power Status	On
Region Code	A
SCADA Fault Status	Normal.TE
SCADA Power Status	On.TE
Sequence	0001

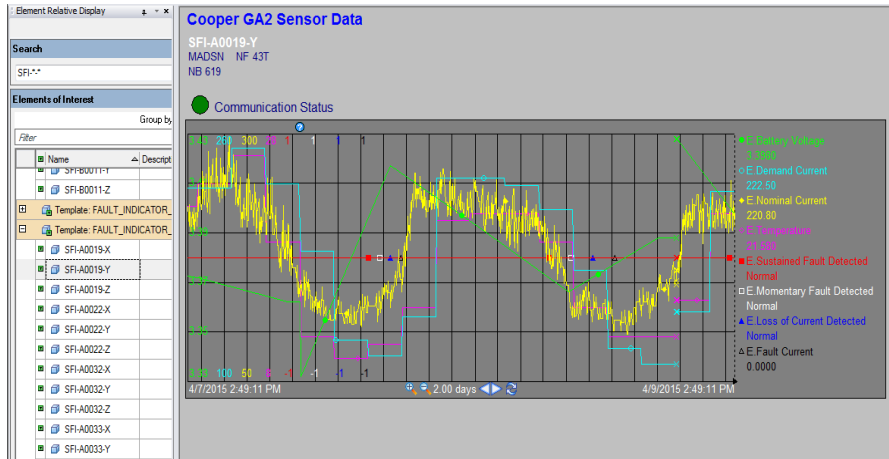
Visualizing Data Using PI Client Tools

PI client tools like ProcessBook and Coresight allow engineers to easily view sensor data for planning and analysis



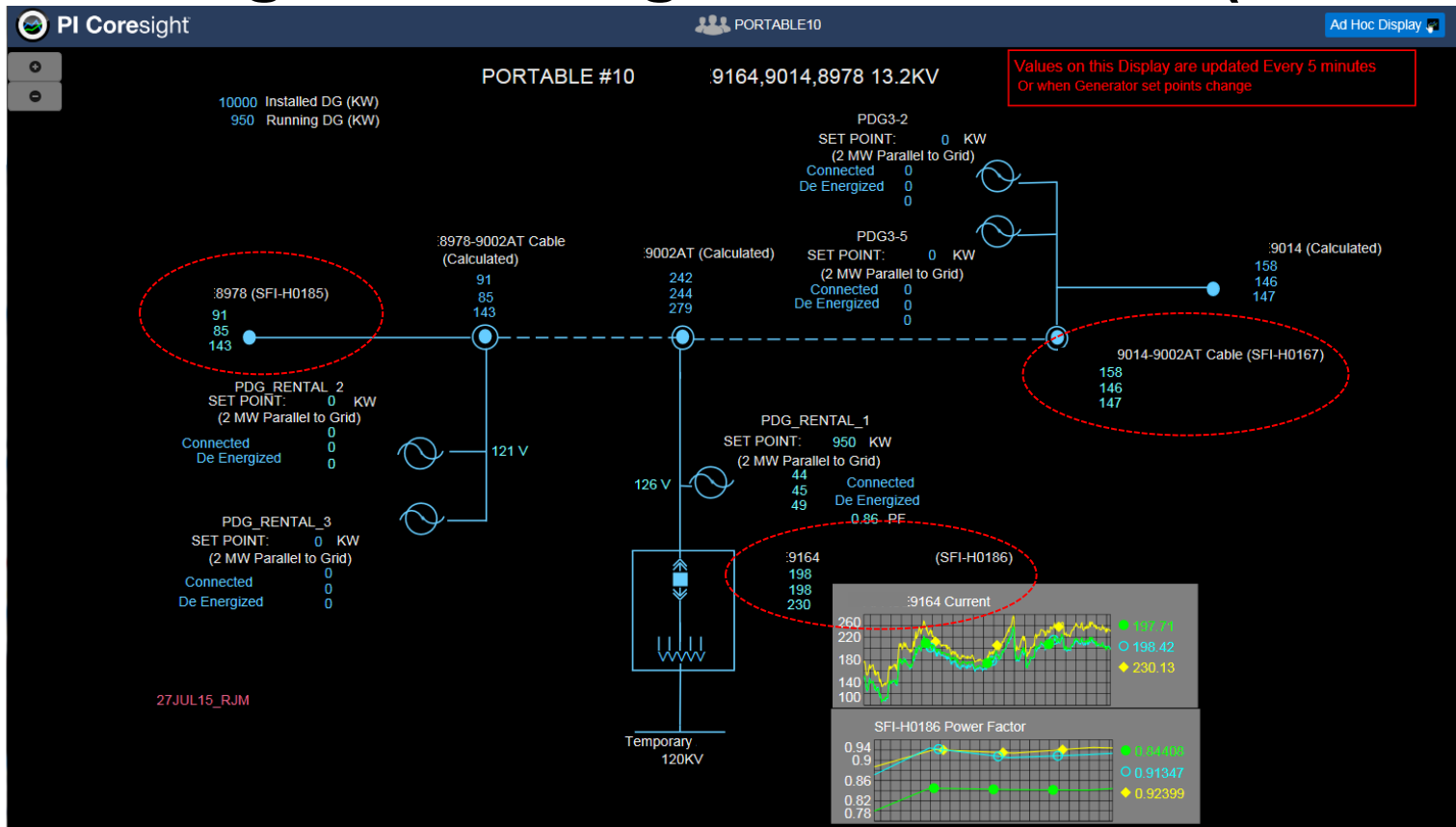
Visualizing Data Using PI Client Tools (cont'd)

- Web-based dashboard (AF-SDK) gives quick overview of circuits
- Element-relative displays allow users to drill-down into sensor data



Circuit	SFI	objectid	Type	X Amps	Y Amps	Z Amps	Power Status	Fault Status	STATUS	Last Update
REDFD1064	SFI-A0001	5450	OUTAGE_ADVISOR_V1 CELLULAR OH	204	174	204	XYZ	XYZ	NORMAL	4/9/2015 2:23:15 PM
REDFD1064	SFI-A0002	5449	OUTAGE_ADVISOR_V1 CELLULAR OH	202	174	200	XYZ	XYZ	NORMAL	4/9/2015 2:23:15 PM
REDFD1064	SFI-A0003	5447	OUTAGE_ADVISOR_V1 CELLULAR OH	66	63	71	XYZ	XYZ	NORMAL	4/9/2015 2:23:15 PM
REDFD1064	SFI-A0004	5446	OUTAGE_ADVISOR_V1 CELLULAR OH	114	98	110	XYZ	XYZ	NORMAL	4/9/2015 2:23:15 PM
REDFD1064	SFI-A0005	5448	OUTAGE_ADVISOR_V1 CELLULAR OH	63	59	60	XYZ	XYZ	NORMAL	4/9/2015 2:23:15 PM
REDFD1064	SFI-A0006	5445	OUTAGE_ADVISOR_V1 CELLULAR OH	63	61	68	XYZ	XYZ	NORMAL	4/9/2015 2:23:15 PM
REDFD1064	SFI-A0007	5443	OUTAGE_ADVISOR_V1 CELLULAR OH	0	5	1	XYZ	XYZ	FAULTED	4/9/2015 2:23:15 PM
REDFD1064	SFI-A0008	9288	OUTAGE_ADVISOR_V1 CELLULAR OH	48	46	42	XYZ	XYZ	NORMAL	4/9/2015 2:23:15 PM
VLLA1555	SFI-A0009	9289	OUTAGE_ADVISOR_V1 CELLULAR OH	69	65	55	XYZ	XYZ	NORMAL	4/9/2015 2:23:15 PM
VLLA1555	SFI-A0010	9290	OUTAGE_ADVISOR_V1 CELLULAR OH	69	40	70	XYZ	XYZ	NORMAL	4/9/2015 2:23:15 PM
VLLA1555	SFI-A0011	9291	OUTAGE_ADVISOR_V1 CELLULAR OH	39	63	42	XYZ	XYZ	NORMAL	4/9/2015 2:23:15 PM
VLLA1555	SFI-A0012	9292	OUTAGE_ADVISOR_V1 CELLULAR OH	35	4	65	XYZ	XYZ	NORMAL	4/9/2015 2:23:15 PM
VLLA1552	SFI-A0013	9295	OUTAGE_ADVISOR_V1 CELLULAR OH	63	122	118	XYZ	XYZ	NORMAL	4/9/2015 2:23:15 PM
VLLA2161	SFI-A0014	9296	OUTAGE_ADVISOR_V1 CELLULAR OH	57	34	40	XYZ	XYZ	NORMAL	4/9/2015 2:23:15 PM
VLLA2161	SFI-A0015	9922	OUTAGE_ADVISOR_V1 CELLULAR OH	39	37	34	XYZ	XYZ	NORMAL	4/9/2015 2:23:15 PM
HAYES1385	SFI-A0016	9923	OUTAGE_ADVISOR_V1 CELLULAR OH	128	128	118	XYZ	XYZ	NORMAL	4/9/2015 2:23:15 PM
MAOSN43T	SFI-A0017	9914	OUTAGE_ADVISOR_V1 CELLULAR OH	0	0	0	XYZ	XYZ	FAULTED	4/9/2015 2:23:15 PM
HAYES1385	SFI-A0018	9922	OUTAGE_ADVISOR_V1 CELLULAR OH	0	0	0	XYZ	XYZ	FAULTED	4/9/2015 2:23:15 PM
MAOSN43T	SFI-A0019	0	GRID_ADVISOR_2 CELLULAR UG	229	221	211	XYZ	XYZ	NORMAL	4/9/2015 2:41:35 PM
TURNR1001	SFI-A0022	0	OUTAGE_ADVISOR_V2 CELLULAR OH	99	115	0	XYZ	XYZ	NORMAL	4/9/2015 2:34:22 PM
BLTMR1395	SFI-A0032	0	OUTAGE_ADVISOR_V2 CELLULAR OH	80	88	93	XYZ	XYZ	NORMAL	4/9/2015 2:34:21 PM
JUPTTR8352	SFI-A0033	0	OUTAGE_ADVISOR_V2 CELLULAR OH	58	74	0	XYZ	XYZ	NORMAL	4/9/2015 2:34:21 PM
JUPTTR8352	SFI-A0034	0	OUTAGE_ADVISOR_V2 CELLULAR OH	38	65	74	XYZ	XYZ	NORMAL	4/9/2015 2:34:21 PM
SYRAC2019	SFI-A0035	0	OUTAGE_ADVISOR_V2 CELLULAR OH	175	192	201	XYZ	XYZ	NORMAL	4/9/2015 2:34:21 PM
JUPTTR8373	SFI-A0040	0	OUTAGE_ADVISOR_V2 CELLULAR OH	184	173	189	XYZ	XYZ	NORMAL	4/9/2015 2:34:21 PM
JUPTTR8373	SFI-A0041	0	OUTAGE_ADVISOR_V2 CELLULAR OH	50	49	45	XYZ	XYZ	NORMAL	4/9/2015 2:34:21 PM
JUPTTR8373	SFI-A0042	0	OUTAGE_ADVISOR_V2 CELLULAR OH	0	0	47	XYZ	XYZ	ABNORMAL	4/9/2015 2:34:21 PM
JUPTTR8373	SFI-A0043	0	OUTAGE_ADVISOR_V2 CELLULAR OH	41	53	77	XYZ	XYZ	NORMAL	4/9/2015 2:34:21 PM
JUPTTR8373	SFI-A0044	0	OUTAGE_ADVISOR_V2 CELLULAR OH	8	18	50	XYZ	XYZ	NORMAL	4/9/2015 2:34:21 PM

Visualizing Data Using PI Client Tools (cont'd)



PI Notifications

Email notifications

From: drsoc@load-watch.com
To: sherdingc@load-watch.com
Subject: ALERT! SUSTAINED FAULT detected: REDFD1064
Date: 2015-04-09 01:40 PM
Priority: Low
Character encoding: Western European (ISO-8859-1)

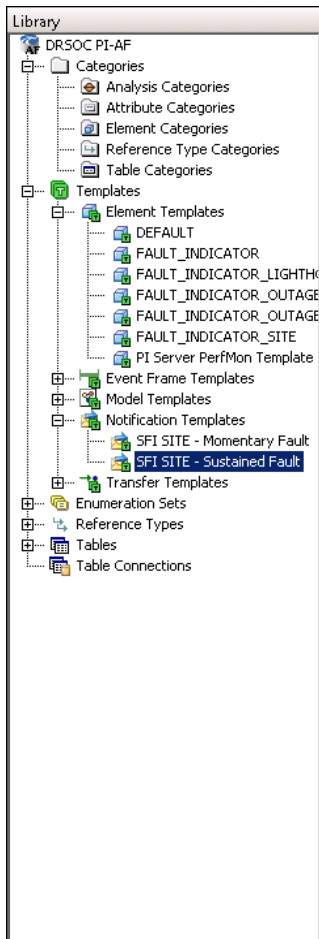
ALERT! Sustained Fault Detected

4/9/2015 1:40:45 PM Eastern Daylight Time (GMT-04:00:00)

Station: REDFD
Circuit: 1064
Location: LW HAZELTON 1PN PILGRIM
OH/UG: OH

Fault Status X: 1
Fault Status Y: 0
Fault Status Z: 0
Fault Current: 1617 Amps

Lat/Long: 42.405733, -83.268618
Sensor Type: FAULT_INDICATOR_OUTAGE_ADVISOR_V1



SFI SITE - Sustained Fault

Overview | Trigger | Message | Subscriptions

Delivery Formats

Name	Delivery Channel
Global Default Email	Email
Sustained Fault Email	Email

Design | HTML Preview | Plain Text Preview

Tahoma 11

Subject

ALERT! SUSTAINED FAULT detected: Device ID:Value

Attachments

Body

ALERT! Sustained Fault Detected

Notification:Trigger Time

Station: SUB:Value
Circuit: CIRCUIT:Value
Location: LOCATION:Value
OH/UG: OHUG:Value

Fault Status X: Sustained Fault Status X:Value
Fault Status Y: Sustained Fault Status Y:Value
Fault Status Z: Sustained Fault Status Z:Value
Fault Current: Fault Current Max:Value Amps

Lat/Long: Latitude:Value, Longitude:Value
Sensor Type: TYPE:Value



PI Notifications

SOAP XML notifications

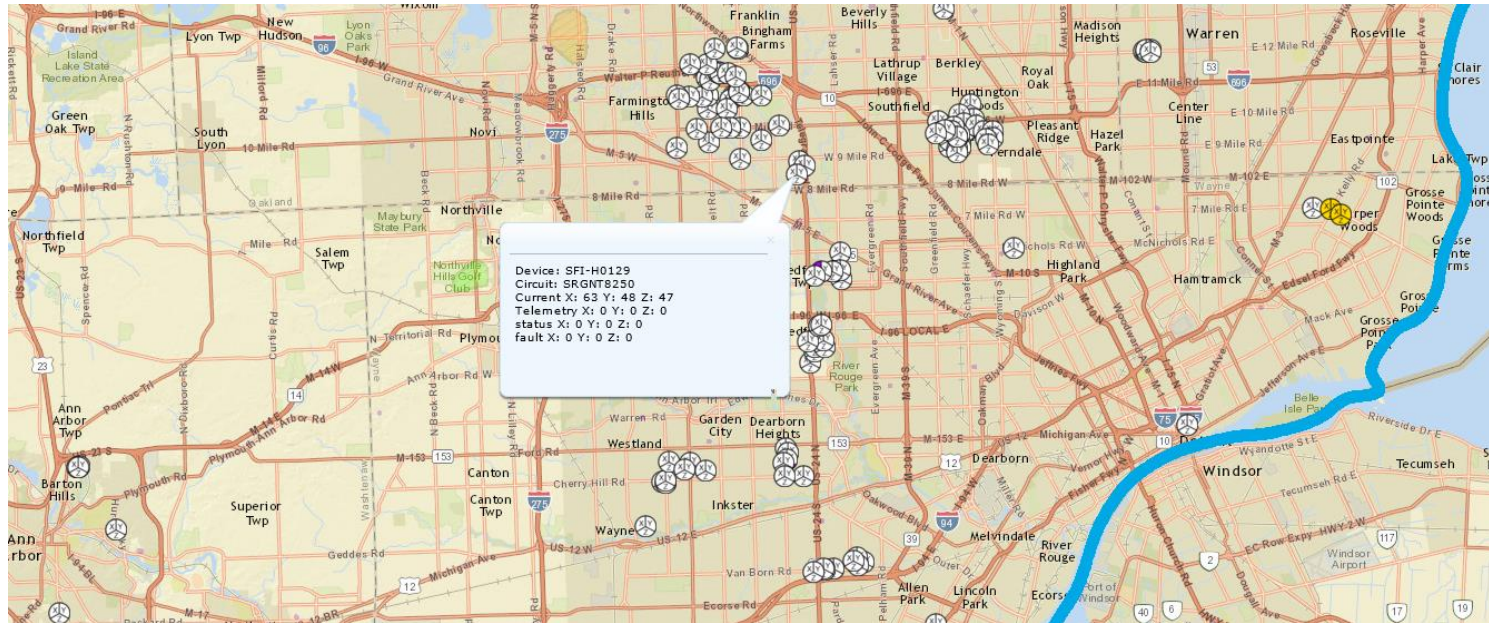
```
<soapenv:Body>
  <dms_ref>13</dms_ref>
  <device_id>REDFD1064</device_id>
  <fault_current_g>243</fault_current_g>
  <fault_current_max>1617</fault_current_max>
  <fault_current_n>1617</fault_current_n>
  <fault_current_x>1617</fault_current_x>
  <fault_current_y>0</fault_current_y>
  <fault_current_z>0</fault_current_z>
  <fault_type>0</fault_type>
  <priority>0</priority>
  <type>FAULT_INDICATOR_OUTAGE_ADVISOR_V1</type>
  <notification_trigger_time>2015-03-25 01:05:19
</notification_trigger_time>
</soapenv:Body>
```

The screenshot displays the OSIsoft software interface for configuring a SOAP XML notification. The 'Library' pane on the left shows the hierarchy: DOPI AF Acc > Categories > Notification Templates > DMS_Fault_Input_XML. The 'DMS_Fault_Input_XML' pane on the right shows the 'Trigger Input' section with a list of attributes, including 'FAULT_INDICATOR_SITE|Fault Current X'. The 'Contacts' pane on the left shows the 'XML_TCP_Fault' contact. The 'XML_TCP_Fault' pane on the right shows the 'Delivery Channel Plug-In Properties' dialog box, where the 'Name' is 'XML_TCP' and the 'Assembly' is 'XML_TCP_DeliveryChannel.dll'. The 'Delivery Channel Plug-In Properties' dialog box is also open, showing the 'General' tab with the 'Name' field set to 'XML_TCP' and the 'Assembly' field set to 'XML_TCP_DeliveryChannel.dll'. The 'File' list at the bottom of the dialog shows 'XML_TCP_DeliveryChannel.dll' with version 1.0.0.0 and date 3/24/2015 6:46:42 AM.



Mapping Fault Status

- Initial proof of concept: Developed Windows service using AF-SDK to push fault events into the GIS database



Mapping Fault Status (cont'd)

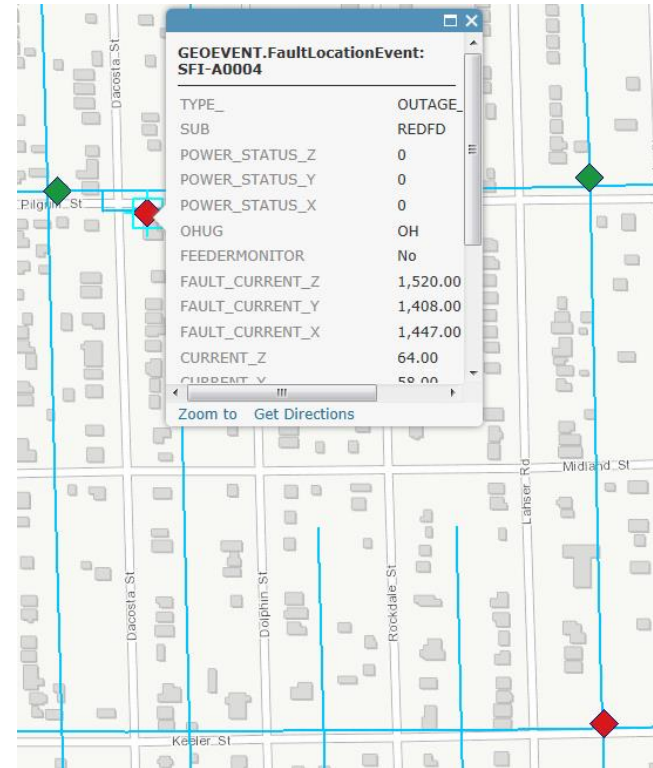
- Next steps: Moving from AF-SDK service to PI Integrator for Esri ArcGIS
- This has also been through proof-of-concept phase
- Expecting full roll-out Q4



Normal



Abnormal



PI Integrator for ArcGIS Configuration

- Template and root element is selected in PI Integrator
- Key fields are identified (key, Latitude, Longitude)
- StreamServer is created and started

Stream Service Layer SFI_Status (0)

Receiving data (169 features received)

☒ Use secure web socket
☐ Use bulk mode (JSON array)

```
{
  "attributes": {
    "objectId": "1419103957",
    "type": "LIGHTHOUSE_MV_SENSOR",
    "sub": "MACMB",
    "power_status_z": null,
    "power_status_y": null,
    "power_status_x": null,
    "ohug": "OH",
    "location": "",
    "glnxy": "",
    "feedermonitor": "Yes",
    "fault_current_z": 0,
    "fault_current_y": 0,
    "fault_current_x": 0,
    "current_z": 78,
    "current_y": 115,
    "current_x": 90,
    "communications": "CELLULAR",
    "circuit": "8409",
    "latitude": 42.50172
```

PI Integrator for Esri ArcGIS Services Administration Tools Help

home / services / FaultLocationGeoService / SFI_Status

Layer SFI_Status

SFI Status

Created on 08/18/2014 02:37:53 (1 month ago), last modified on 08/28/2014 06:41:21 (1 month ago)

All Features Fields StreamServer DisplayServer ArcGIS

This layer exposes the following fields

Name	Attribute Name
TYPE	TYPE
SUB	SUB
Power_Status_Z	Power Status Z
Power_Status_Y	Power Status Y
Power_Status_X	Power Status X
OHUG	OHUG
LOCATION	LOCATION
GLNXY	GLNXY
FEEDERMONITOR	FEEDERMONITOR

Layer SFI_Status

SFI Status

Created on 08/18/2014 02:37:53 (1 month ago), last modified on 08/28/2014 06:41:21 (1 month ago)

All Features Fields StreamServer DisplayServer ArcGIS

This layer is exposed as a StreamServer within the [services directory](#)

Layer connections

Show: All Time: *-1d ☒ Automatic refresh Clear

Status	Updates	Total data	Host	Address	Secure	Created	Updated	Total time	Time since last	Avg update rate	Avg data rate
✓ Opened	143	151.3 kB	162.9.162.252	162.9.162.252	✓	just now	just now	00:00:07	00:00:21	18.15 updates/s	19.2 kB/s



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Operationalizing the Data

- Circuit Level outage on MANDY0308 at 6 AM
- Based on previous circuit history, initial response from SOC was to treat circuit outage as a cable fault
- Overhead supervisor had access to data from a rapid experiment utilizing mobile map overlaid with fault data from intelligent field devices
- Overhead supervisor guided crew to the section of the circuit impacted by the fault, reducing patrol time
- Cause was a tree taking down XY phase on overhead
- Determination could have been made within 5 minutes of initial outage to send crew to do restore before repair



 Fault Indicator
 AMI Meters

DTE Energy: Reliability Through Innovation

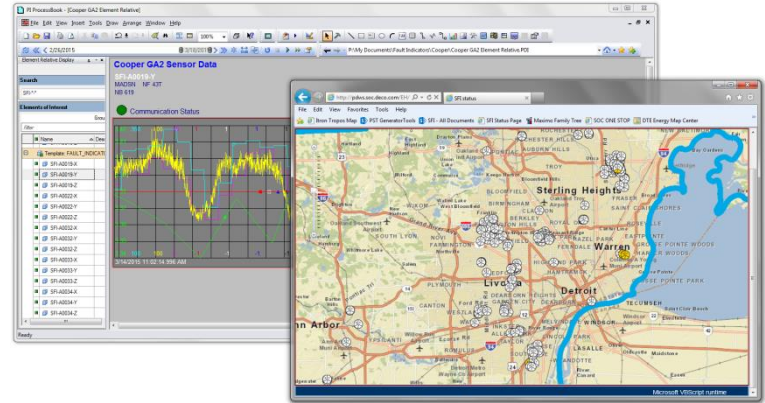
“As an innovative utility, we were looking for solutions to get more real-time reliability data out of our distribution grid, particularly on older legacy and poorly performing circuits.”

“Now that we have better real-time visibility into our grid, we can safely restore power faster and better plan our capital investments around aging assets before they cause outages.”

Vince Dow

Vice President, Distribution Operations, DTE Energy

DTE Energy



Business Challenges

- Determining where to send crews during outages to minimize patrol time
- Integrating data from different types of sensors with multiple backend systems
- Allow crews to visualize real-time sensor data in the field and engineers to visualize historical data in the office

Solution(s)

- Feed all sensor data into PI System using PI DNP3 interface
- Utilize PI AF and PI Notifications to push events to field and DMS
- Coresight and ProcessBook to visualize historical data
- Utilize PI integrator for Esri ArcGIS

Results and Benefits

- Visualization of sensor status on circuit map allows crews to divide circuit into segments and narrow search for faults. Expecting to eliminate at least **500k customer outage minutes** annually
- History of device operation and circuit data gives valuable visibility into legacy parts of the system. Savings estimated at **\$25k per circuit**.

Cameron D. Sherding

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Sr. Software Engineer

Power Systems Technology

DTE Electric Company

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