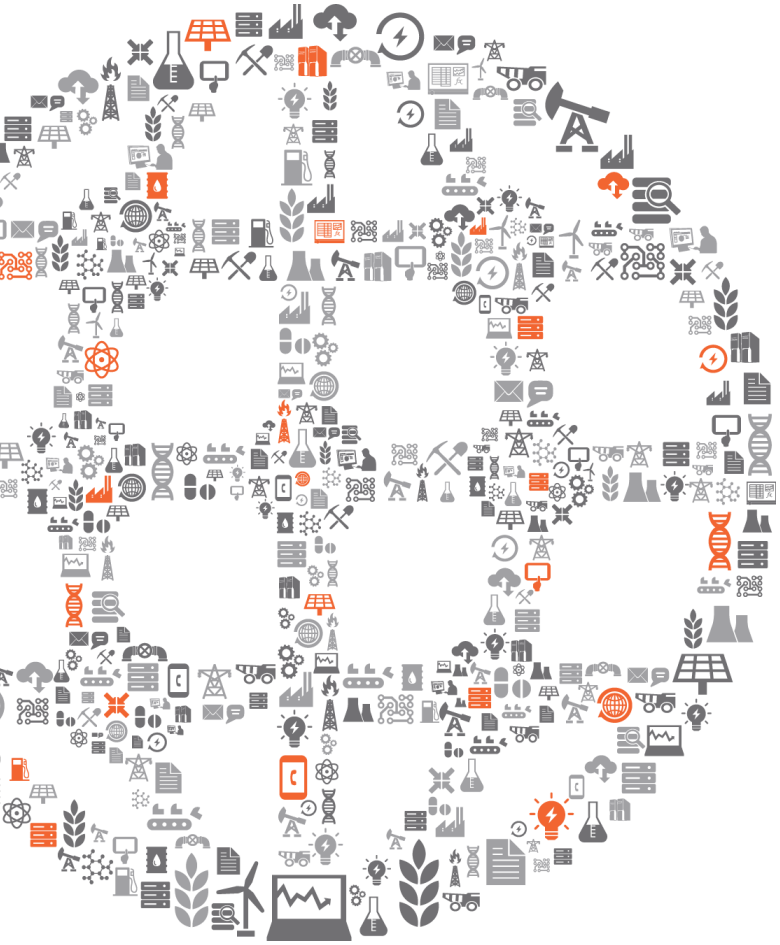
OSIsoft.

REGIONAL SEMINAR

The Power of Data

THRIVING IN A WORLD OF CHANGE



Industry Trends of "PI" for T&D Utilities

Presented by **Ann Moore, OSIsoft, LLC**

PI System for Transmission

California ISO – *"On the front Lines of the Power Grid"*
- New York Times, October 2011

PJM – "Information Technology Unleashes the Electric Equivalent of a Free Keystone Pipeline" **-** Forbes - March 2012

CAISO
California Independent System Operator

Solution is helped if you think this way

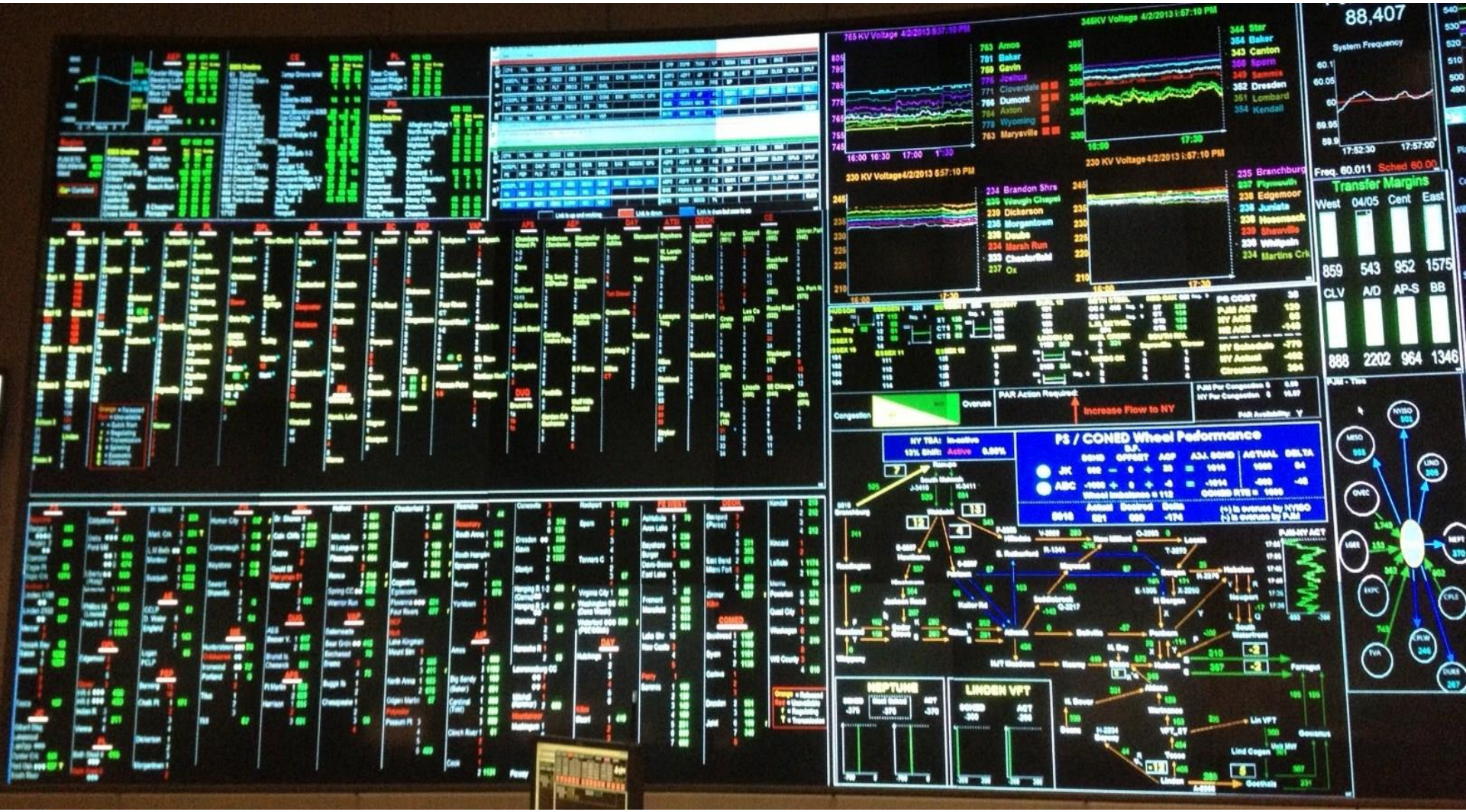
- EMS provides reality and a way to operate reality
- The market is the forecast of the reality to come
- We need to provide operators visualization to tie the past, current, and the future
- Operators' confidence is increased as you provide the visualizations and accuracy of the forecast

PI is the continuum for operators to see and analyze the past, operate the current, and proactively make decisions to prevent a negative future

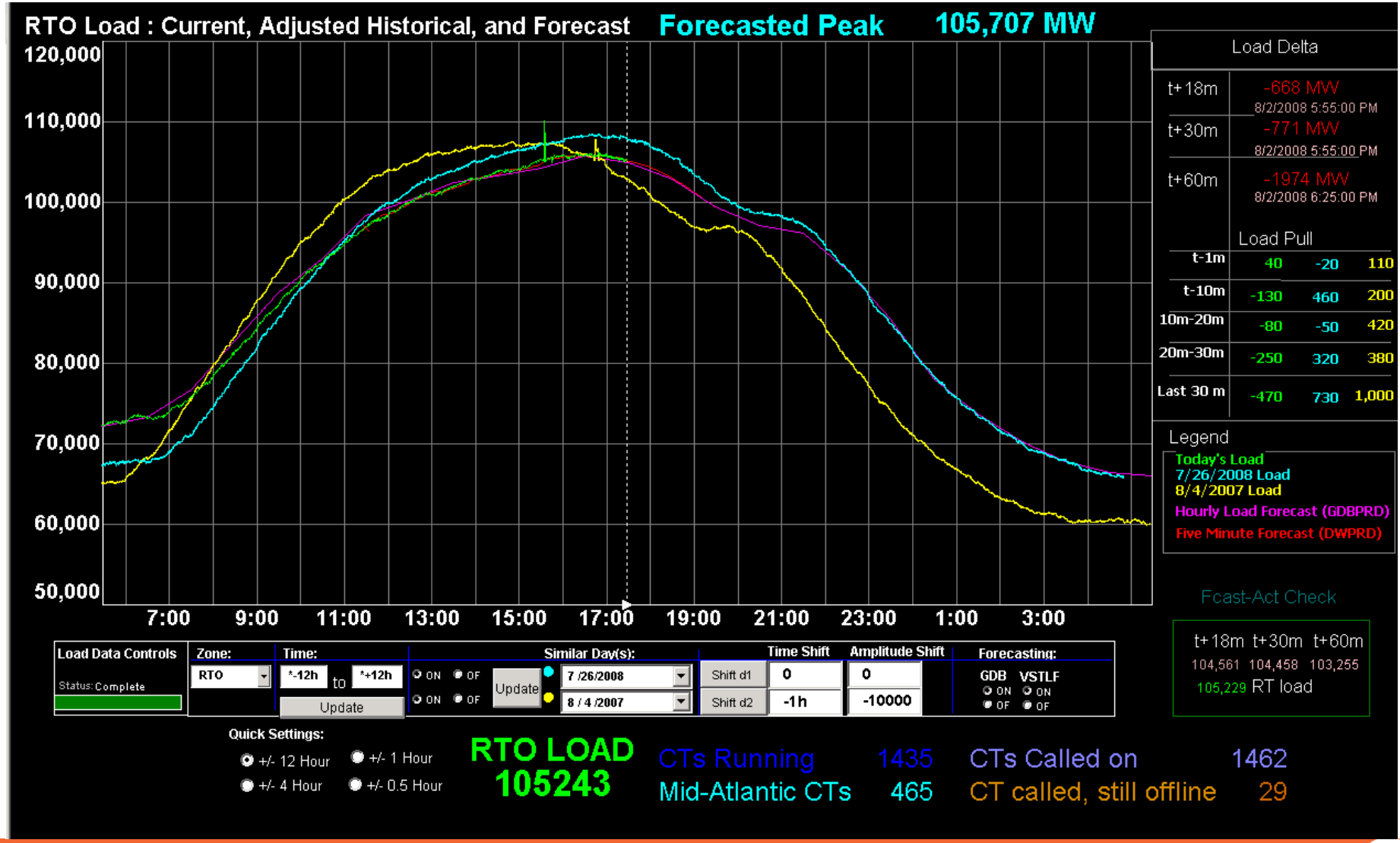
PJM Overview

- PJM is a Regional Transmission Organization (RTO)
  - Coordinates the movement of wholesale electricity in all or parts of 13 states and Washington D.C.
  - Operates wholesale electricity market
  - Manages the high-voltage electricity grid to ensure reliability for more than 60 million people
  - Peak Demand is ~163,000 MW
  - Peak Capacity is ~185,000 MW
  - PJM territory includes 6,000 substations
  - 62,000 miles of transmission lines (69KV-765KV)
  - Dispatch 1,200 Generators

PJM Control Center Video Wall



Load Forecast and Historical Load Curves



PG&E (Pacific Gas & Electric)

Electricity and Gas

- Northern and Central California
- 15 million people
- 70,000-sq-mile service area
- 140,000 circuit miles
- All-time Peak over 23,000MW

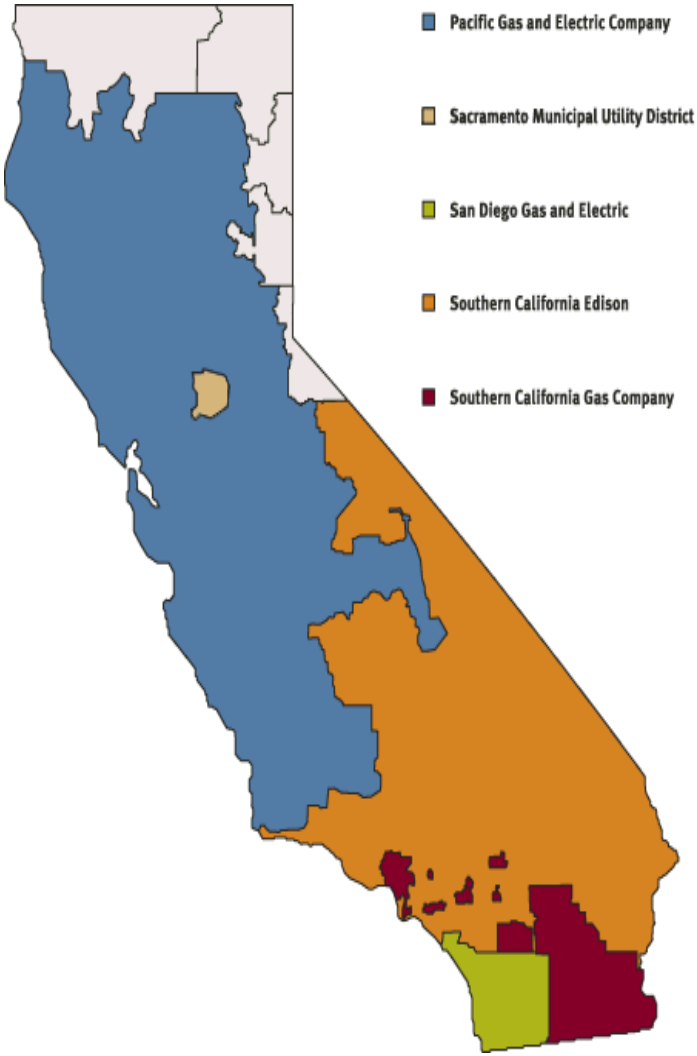
Serve 1 in 20 Americans.

Transmission (Circuit Miles)

500 kV	1,330
230 kV	5,420
115 kV	6,230
60/70 kV	5,660
Total	18,640

Substations

Transmission	142



Grid Operations - The situation:

- Transmission facilities change constantly
  - 40 to 60 maintenance operations per day
- Each chance removes grid resources and increases power flows in remaining resources
- Grid operators need:
  - A grid design that re-routes power
  - Assurance that re-routed power is safe and reliable

In other words, every day is a new grid

Today – a spreadsheet

From

A Spreadsheet

- Manually generated
- 30-60 times per day

Moraga #1-230/115kV Bank (->)		77		
0.29*Moraga #3-230/115kV Bank (->)		64		Limit
	Total	141	MW	180
San Mateo #7-230/115kV Bank Cleared		SLIC	188188	4/22-6/30
Pre-Clearance Requirement - Flow Limit #1				
Ravenswood-San Mateo 115kV Line (-> @ Ravenswood)		44		
0.11 * San Mateo 230/115kV Bank #5		21		
0.11 * San Mateo 230/115kV Bank #7		0		Limit
	4 fps 1000 - 1900 Total	64	MW	115
	1900 - 1000 Total	64	MW	100
Real Time Requirements - Flow Limit #1				
Ravenswood-San Mateo 115kV Line (-> @ Ravenswood)		44		
0.11 * San Mateo 230/115kV Bank #5		21		
	4 fps 1000 - 1900 Total	64	MW	115
	1900 - 1000 Total	64	MW	100

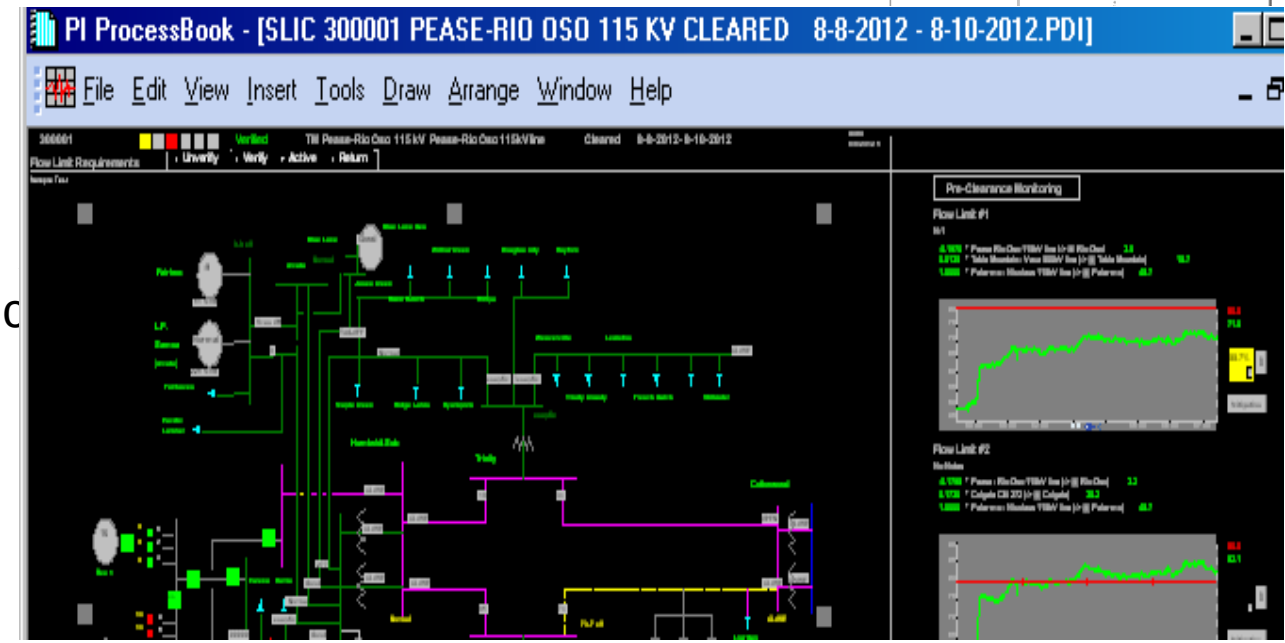
To

A Graphic

Click and search data into PI

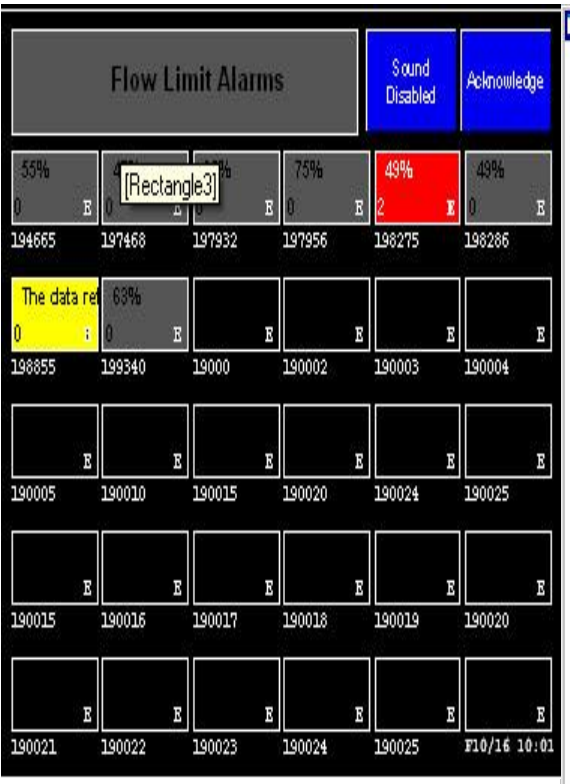
Automatically produce graphic

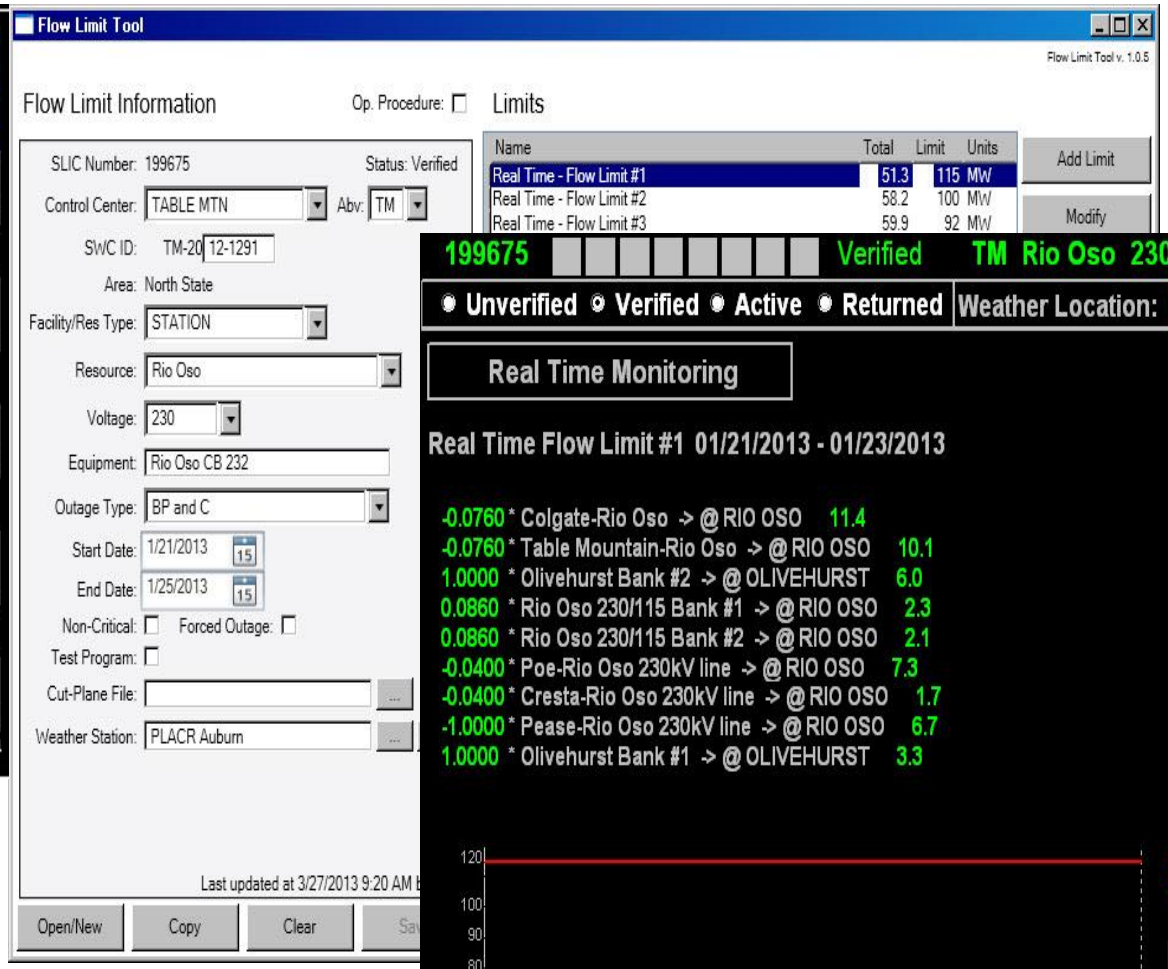
- one-lines
- flow trends
- alarms



Title, alarm, one-line and flow limit at a glance

The Solution – PI Flow Limit Tool





- **Flow Limit Tool**
- **Output via**
  - **Limit Screen**
  - **Alarm Annunciator**

Benefits: Enhanced Situational Awareness

Trends

- *Visual Proximity to Limit*
- *Rapid Situational Assessment*

Alarming

- *Audible*
- *Staged 85%,95% & 100%*
- *Color Coded*

Weather

- *Real-Time Temperature*
- *Wind measurements*

Data Quality

- *Displays EMS quality (Good, Suspect, Replaced or Estimated)*

Efficiency

- *Reduced Set-up time*
- *Lower Training Time*

Financial

- *Accurate implementation of actual limits*
- *Customer Power Outages are Expensive*

Security

- *PI is a stable platform (few glitches)*
- *Equipment 'At Risk' is more secure*
- *Customer Power Outages*

Safety

- *Crews working on equipment*
- *Equipment itself*

PI System for Distribution

Electric Distribution
Many changes…

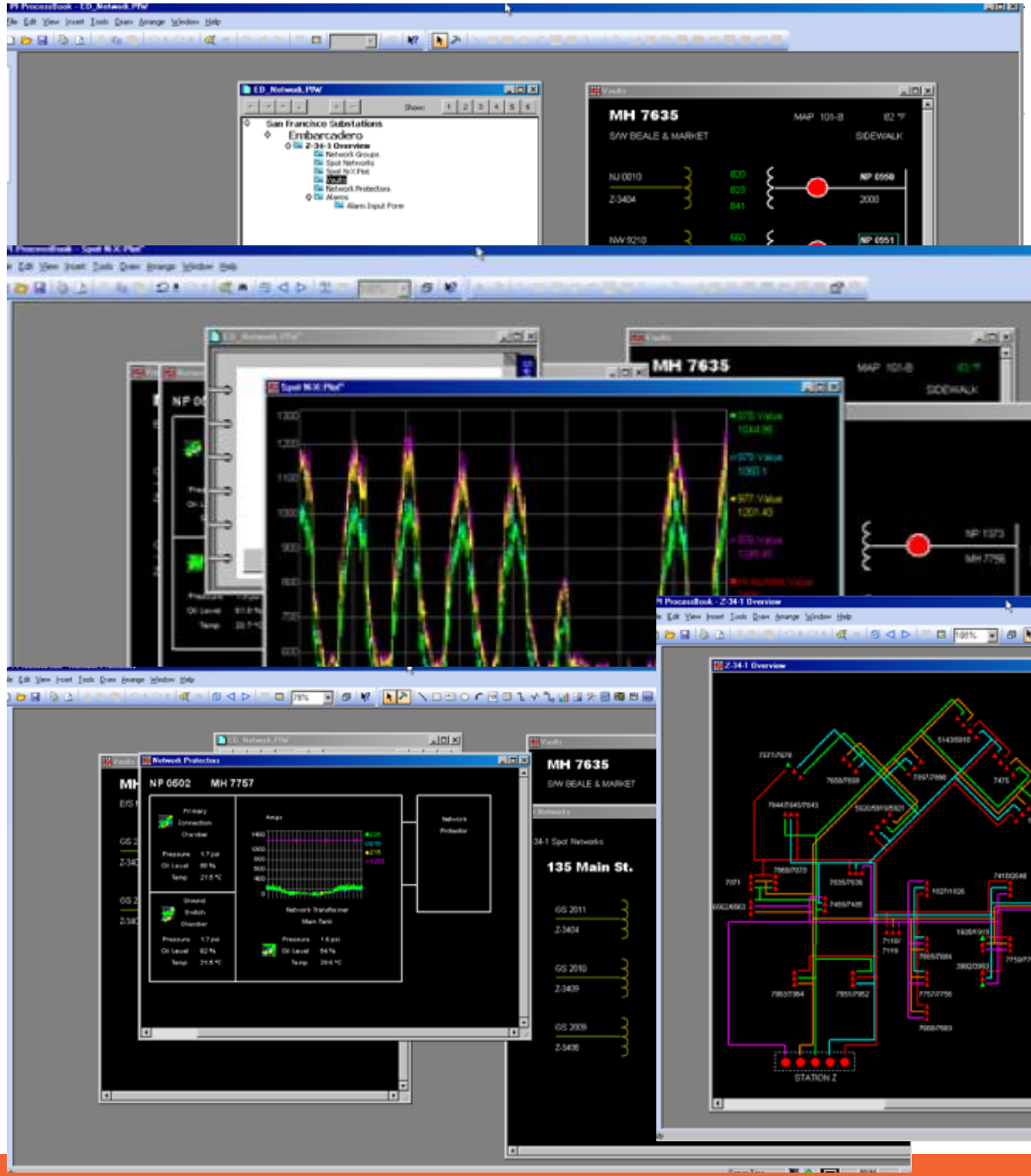
- Fault Location Isolation System Restoration (FLISR)
- Distribution Control Center Consolidation – From 13 to 3
- New Technology: Asset Management / GIS / DMS
- SCADA Major Version Upgrade / New PI Interface
- New Data Center

Project Requirements

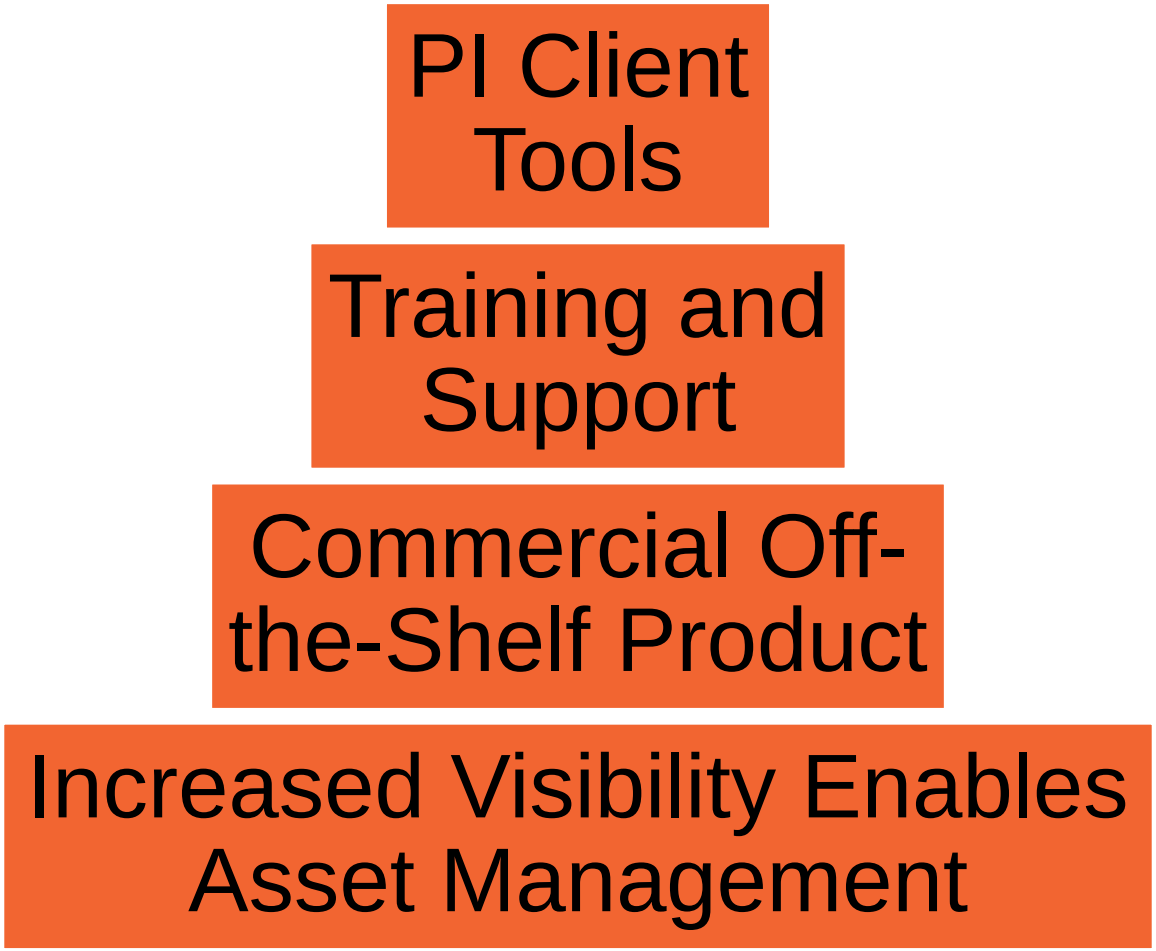
Monitor	• Over 1,000 Transformers just in San Francisco and Oakland
Historize	• Collect data for Condition Based Maintenance
Notify	• E-mail and text alerts on alarm conditions
Visualize	• Provide a user interface to easily find assets and their data trends

Solution Objectives

- Meet requirements with out-of-the-box PI System services and applications
- Fully exploit extensibility provided by:
  - PI ProcessBook VBA
  - PI Calculations / Performance Equations
  - PI AF Templates and Data References
  - PI AF for Analytics and Notifications
  - Element Relative Displays



Benefits



PI System as the Enterprise Data Infrastructure for Smart Grid

SDG&E - San Diego Gas & Electric

GAS SYSTEM

PIPELINE

GAS T&D

GAS STORAGE

ELECTRICAL SYSTEM

GENERATION

SUBSTATIONS

T&D OPERATIONS

T & D CBM

IT Data Center

OSIsoft PI Systems at SDG&E

GAS SYSTEM

PIPELINE

GAS T&D

GAS STORAGE

ELECTRICAL SYSTEM

GENERATION

Transmission & Distribution

CBM

SUBSTATIONS

T&D OPERATIONS

T & D CBM

IT Data Center

Key Reasons For Adopting Enterprise Approach

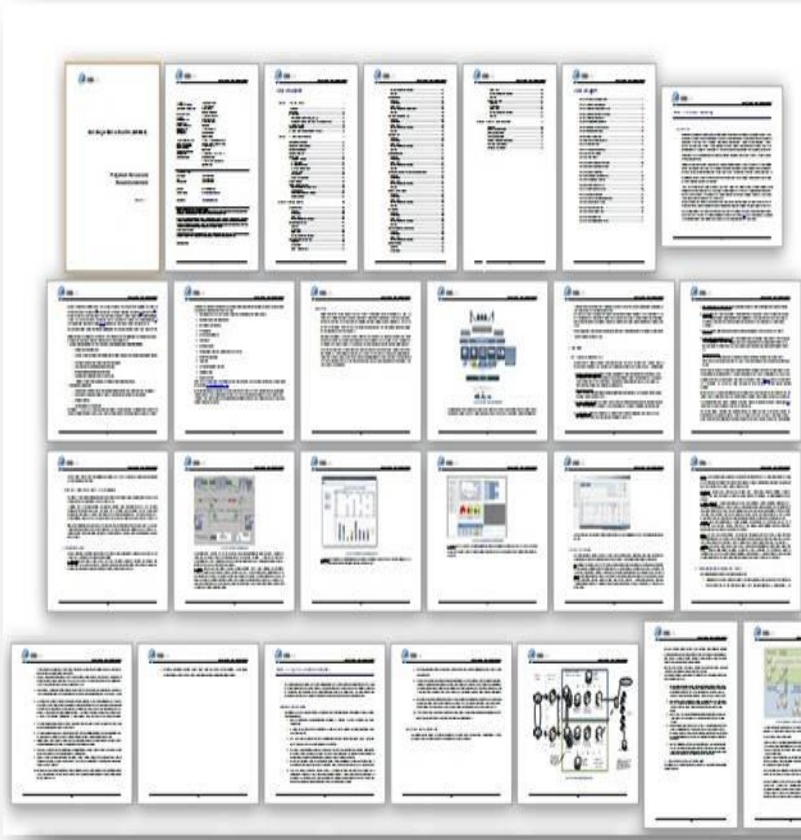
- **Vendor Management**
  - SDG&E has multiple instances of PI installed across the business areas.
  - Procurement effort was an order of magnitude greater in the site-by-site approach.
  - Excessive time required to negotiate each new project
- **Internal Support**
  - Lack of ownership for applications & configuration management
- **Architecture**
  - Inconsistent infrastructure standards-Security,Redundancy,SoftwareTools and Upgrade
  - Application Integration was fragmented
- **Missed Opportunities**
  - Data was under utilized (silos)
    - Missed business application (SmartGrid)
  - Under utilized operational (PI) and business data for real time decision making

Success Criteria

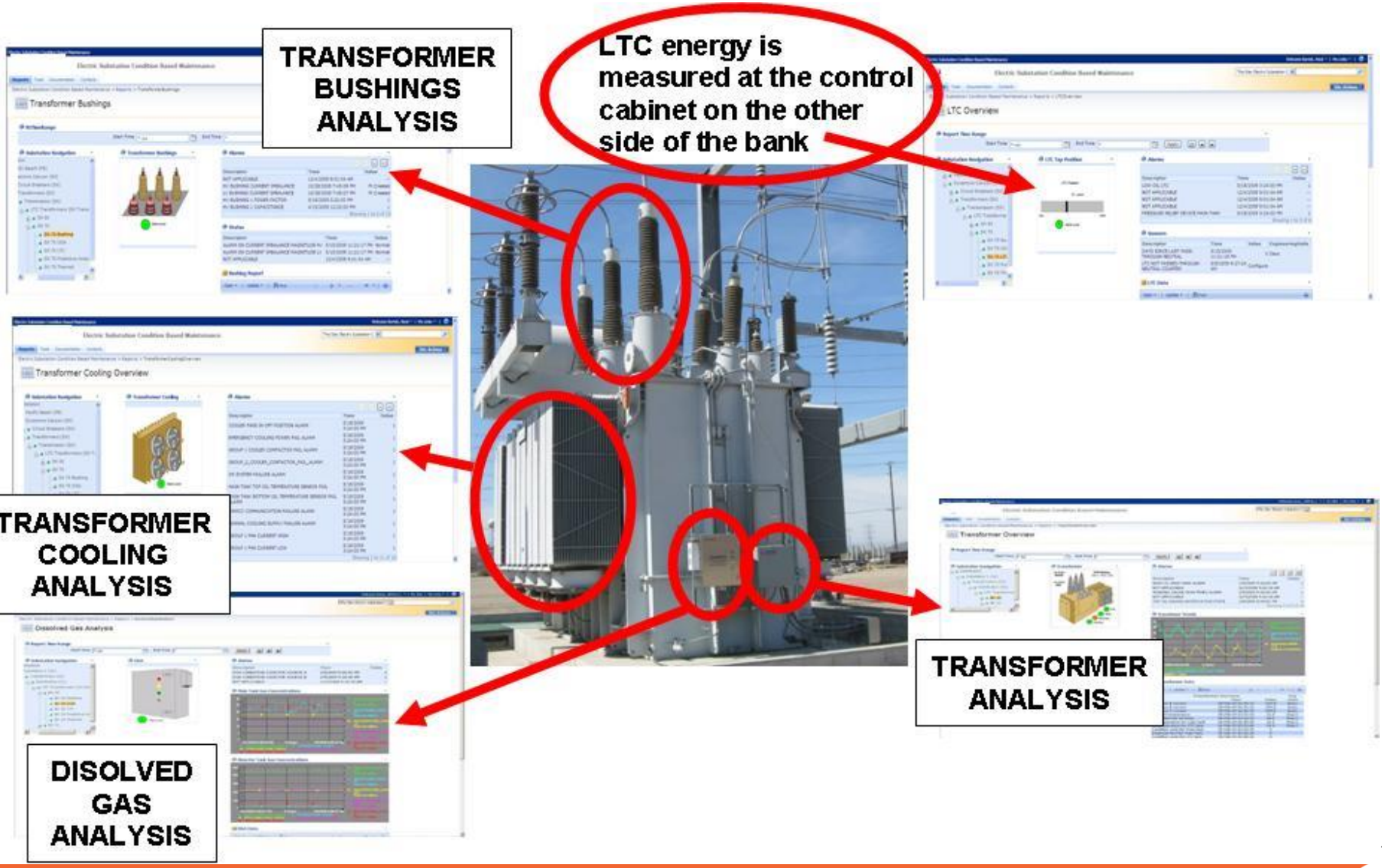
- Manage total cost of ownership while meeting growing business needs
- Empower PI system users at SDG&E
- Support Smart Grid Initiatives and Future Use Cases

PI System for Smart Grid

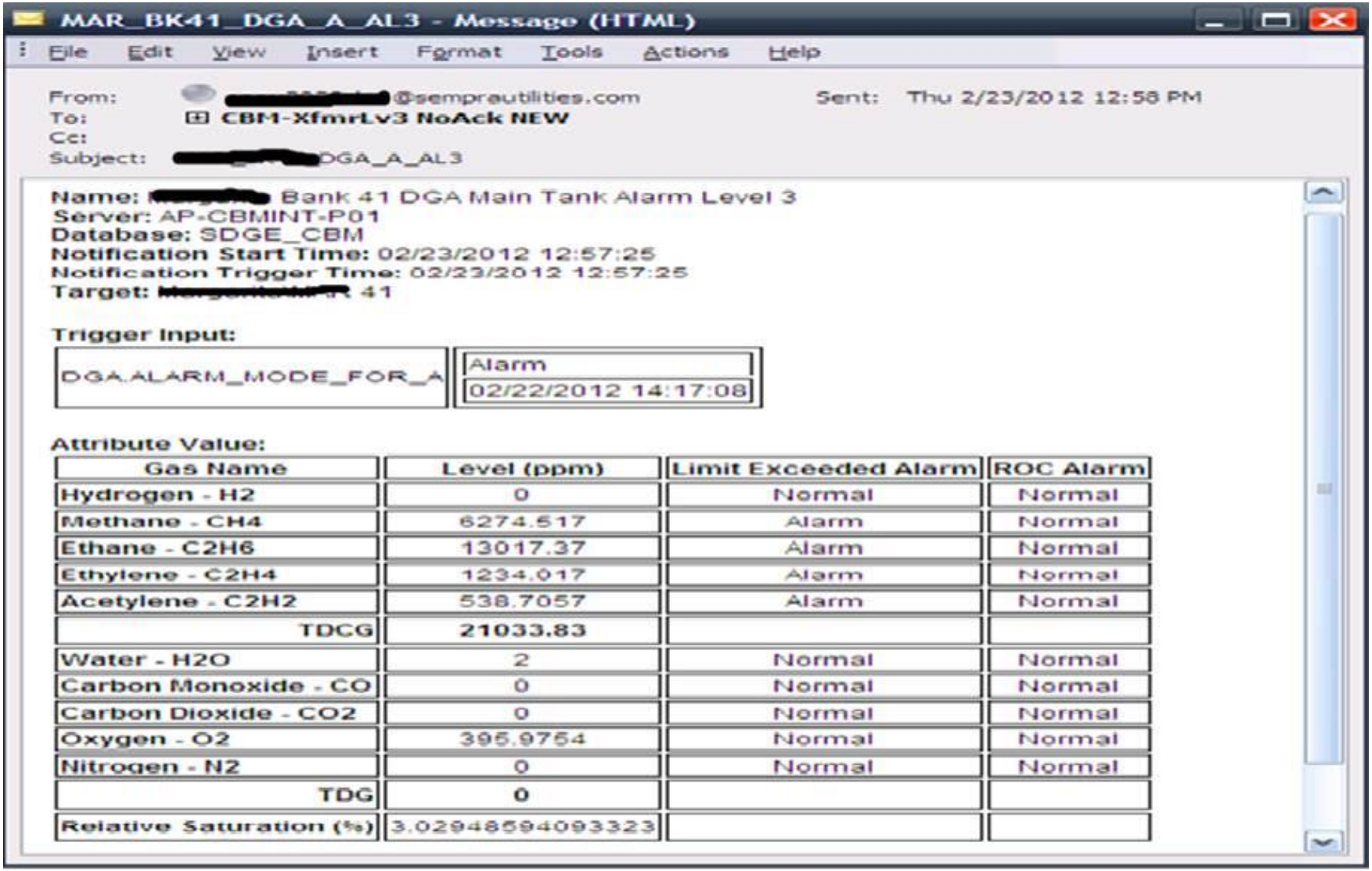
- Condition Based Mainteance (CBM)
- Gas Meter Events Processing
- Synchrophasors
- Low Power Communication Network (Wireless)
- Sustainable Communities and Substation PV
- Smart Meter Data Collection (Cell Relay health)
- Weather Data Analysis
- Borrego Springs Microgrid
- Advanced Energy Storage (AES)
- Dynamic Voltage Support
- EV-Electric Vehicle Detection
- Dynamic Line Rating
- Distribution Phase Imbalance



Condition Based Maintenance



PI Notifications for CBM



MAR_BK41_DGA_A_AL3 - Message (HTML)

File Edit View Insert Format Tools Actions Help

From: [redacted]@semprautilities.com
To: CBM-XfmrLv3 NoAck NEW
Cc:
Subject: [redacted]DGA_A_AL3
Sent: Thu 2/23/2012 12:58 PM

Name: [redacted] Bank 41 DGA Main Tank Alarm Level 3
Server: AP-CBMINT-P01
Database: SDGE_CBM
Notification Start Time: 02/23/2012 12:57:25
Notification Trigger Time: 02/23/2012 12:57:25
Target: [redacted] 41

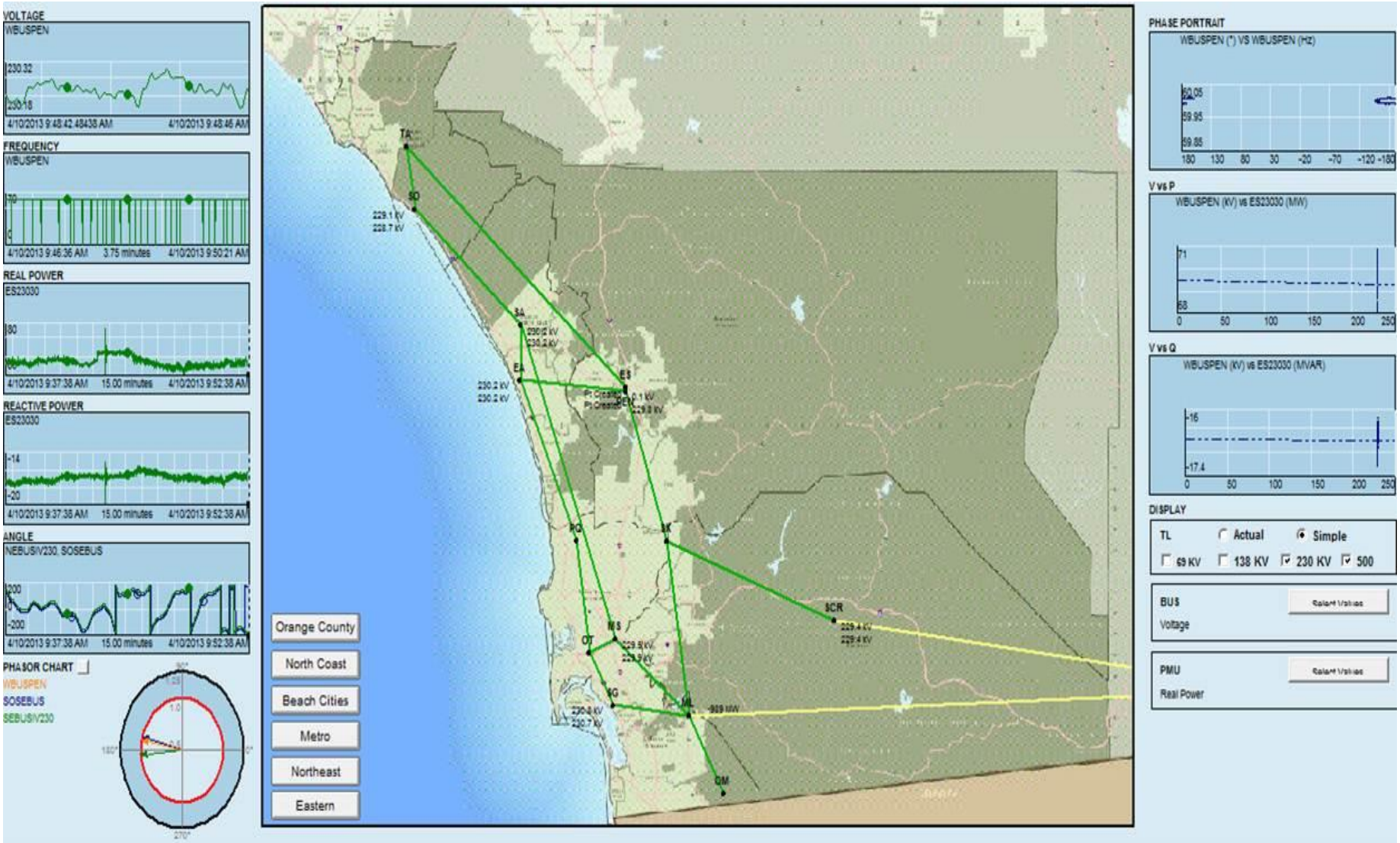
Trigger Input:

DGA.ALARM_MODE_FOR_A	Alarm
	02/22/2012 14:17:08

Attribute Value:

Gas Name	Level (ppm)	Limit Exceeded Alarm	ROC Alarm
Hydrogen - H2	0	Normal	Normal
Methane - CH4	6274.517	Alarm	Normal
Ethane - C2H6	13017.37	Alarm	Normal
Ethylene - C2H4	1234.017	Alarm	Normal
Acetylene - C2H2	538.7057	Alarm	Normal
TDCG	21033.83		
Water - H2O	2	Normal	Normal
Carbon Monoxide - CO	0	Normal	Normal
Carbon Dioxide - CO2	0	Normal	Normal
Oxygen - O2	395.9754	Normal	Normal
Nitrogen - N2	0	Normal	Normal
TDG	0		
Relative Saturation (%)	3.029485940933 23		

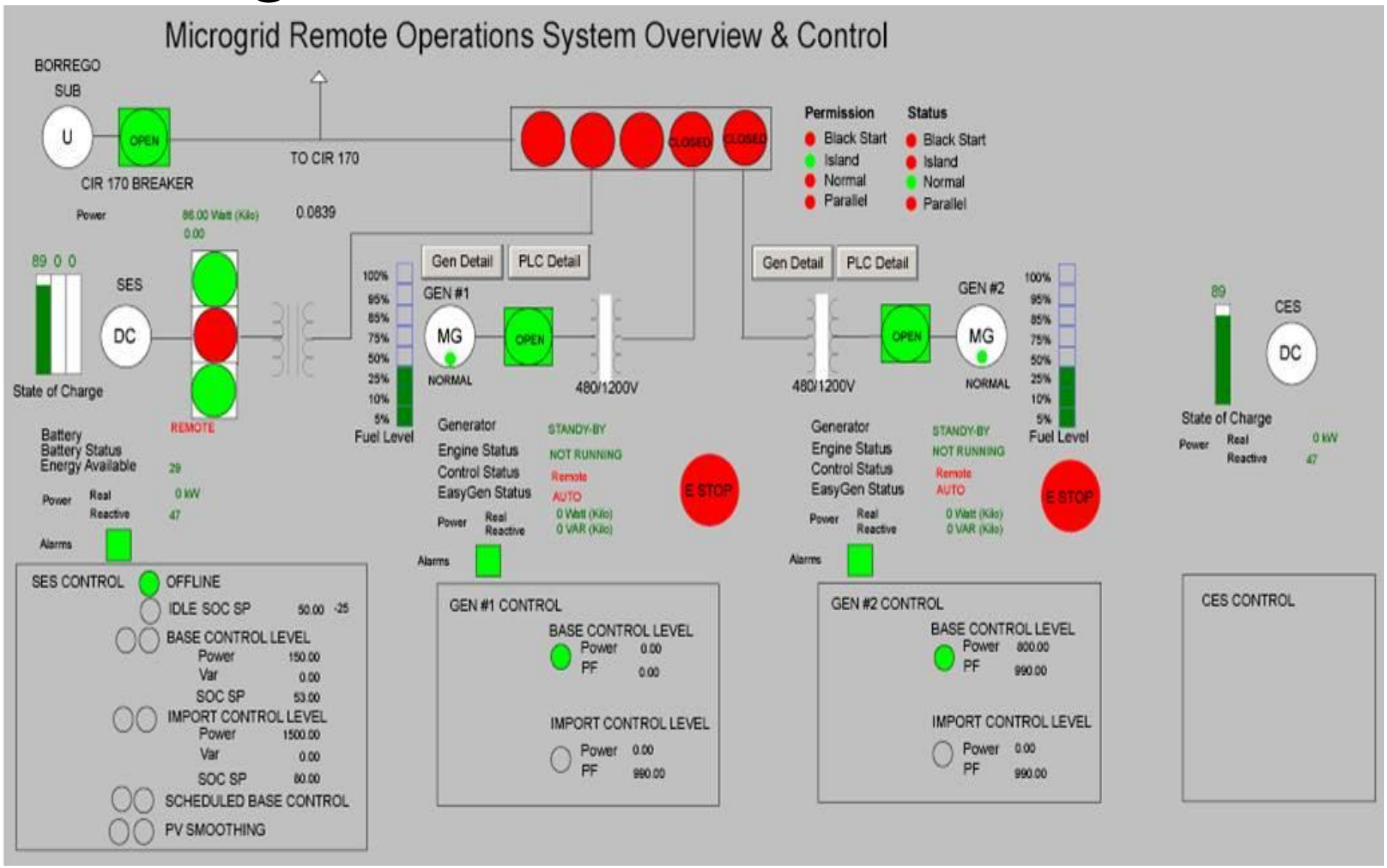
Synchrophasors



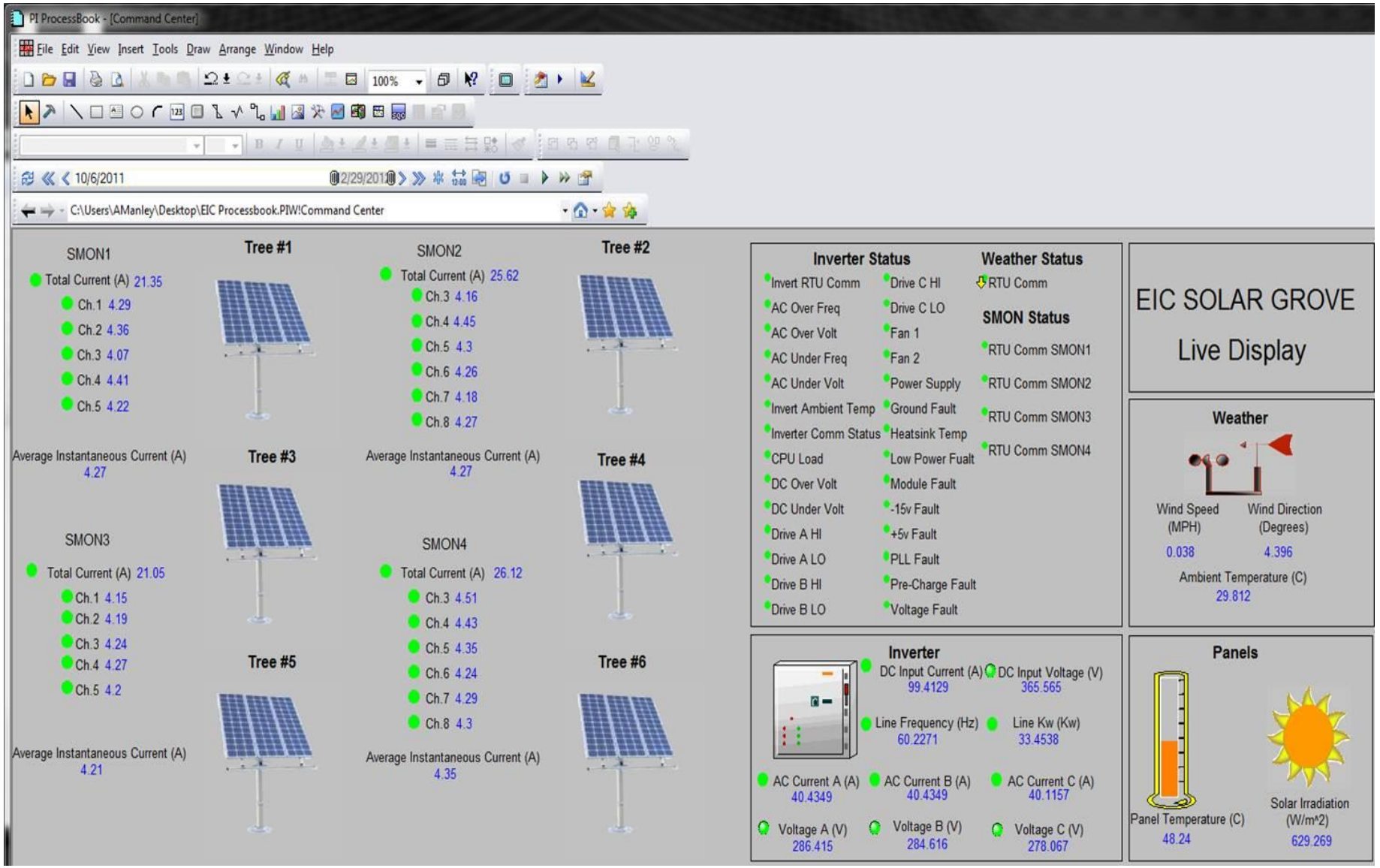
Borrego Springs Microgrid

- Integrate and leverage various generation and storage configurations.
- Reduce the peak load feeders and enhance system reliability.
- Enable customers to become more active participants in managing their energy usage.

Microgrid



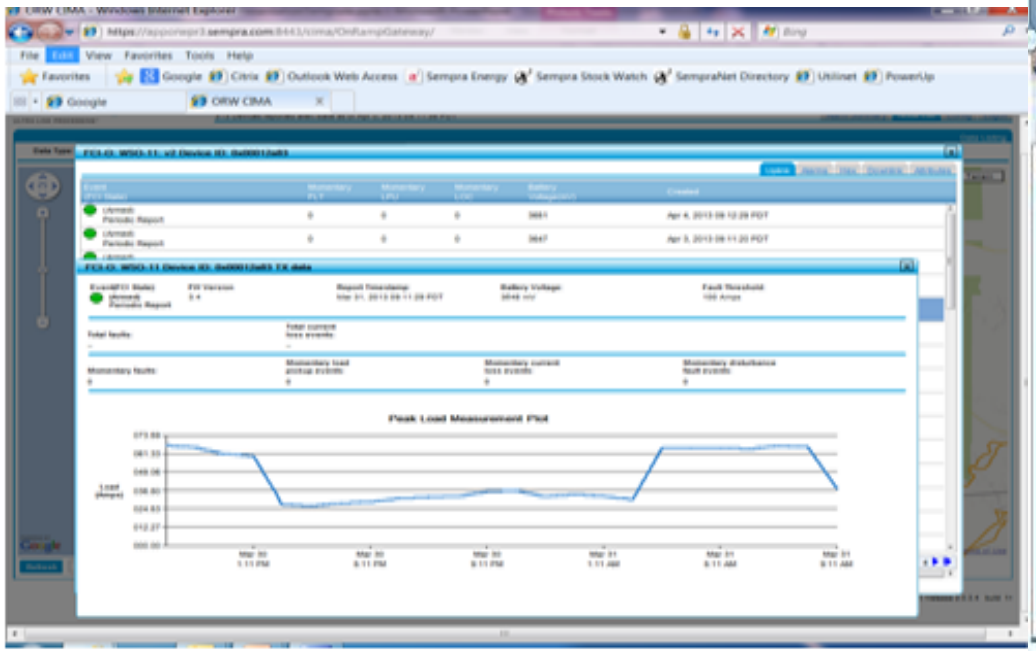
Solar Integration

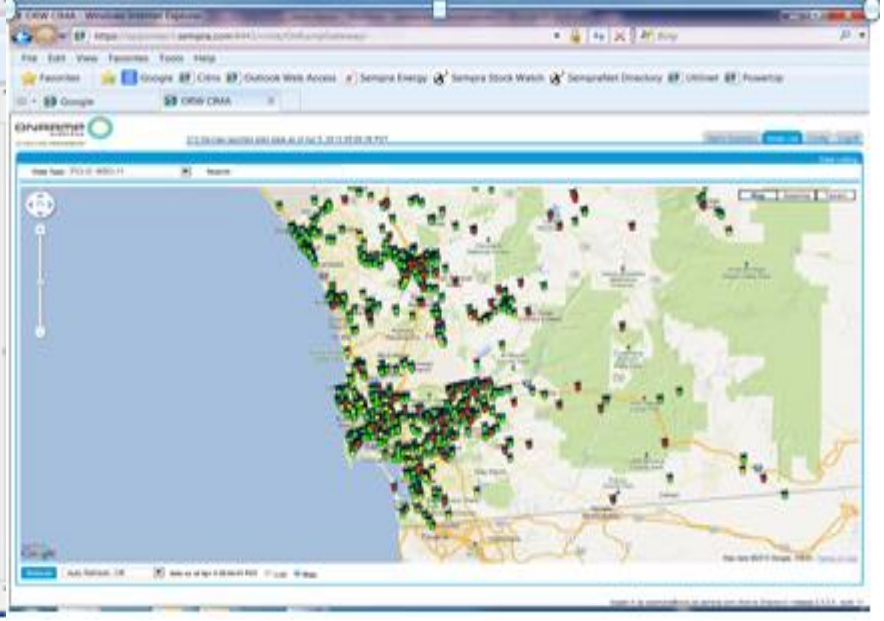


Renewables Integration

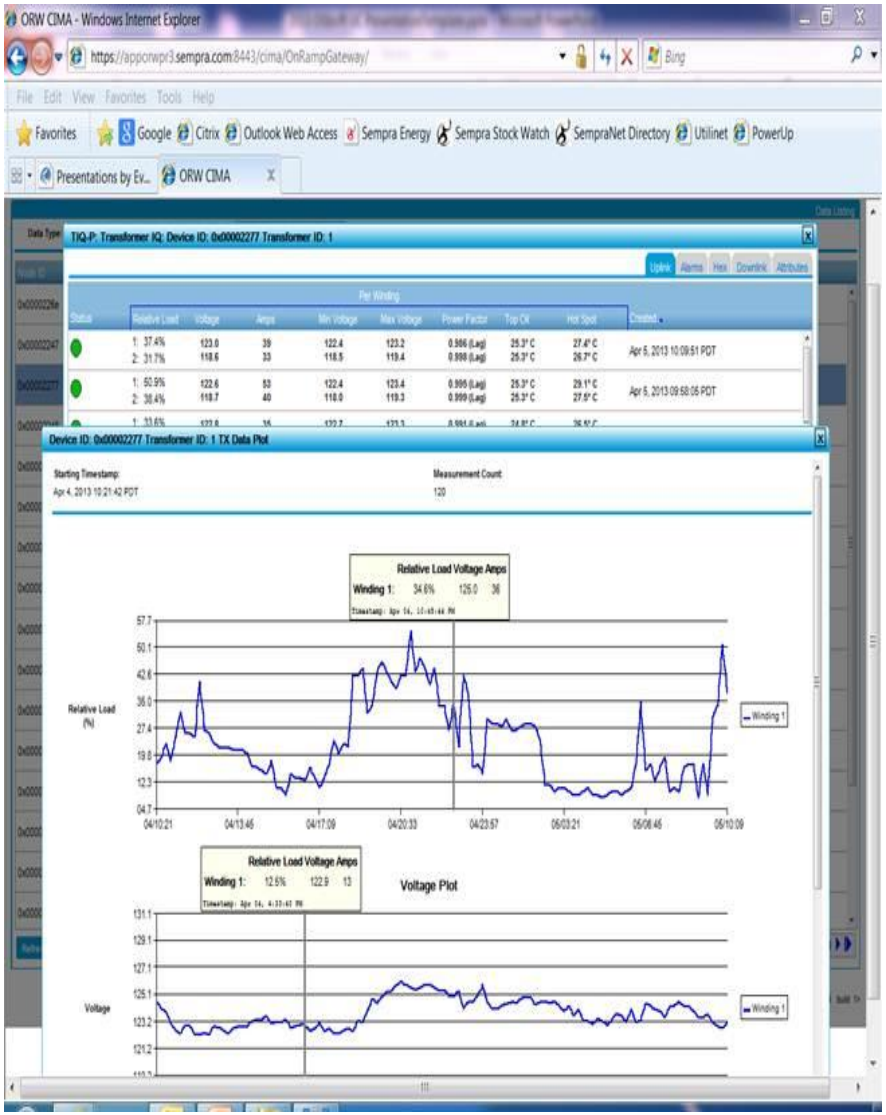
Low Power Communication Network

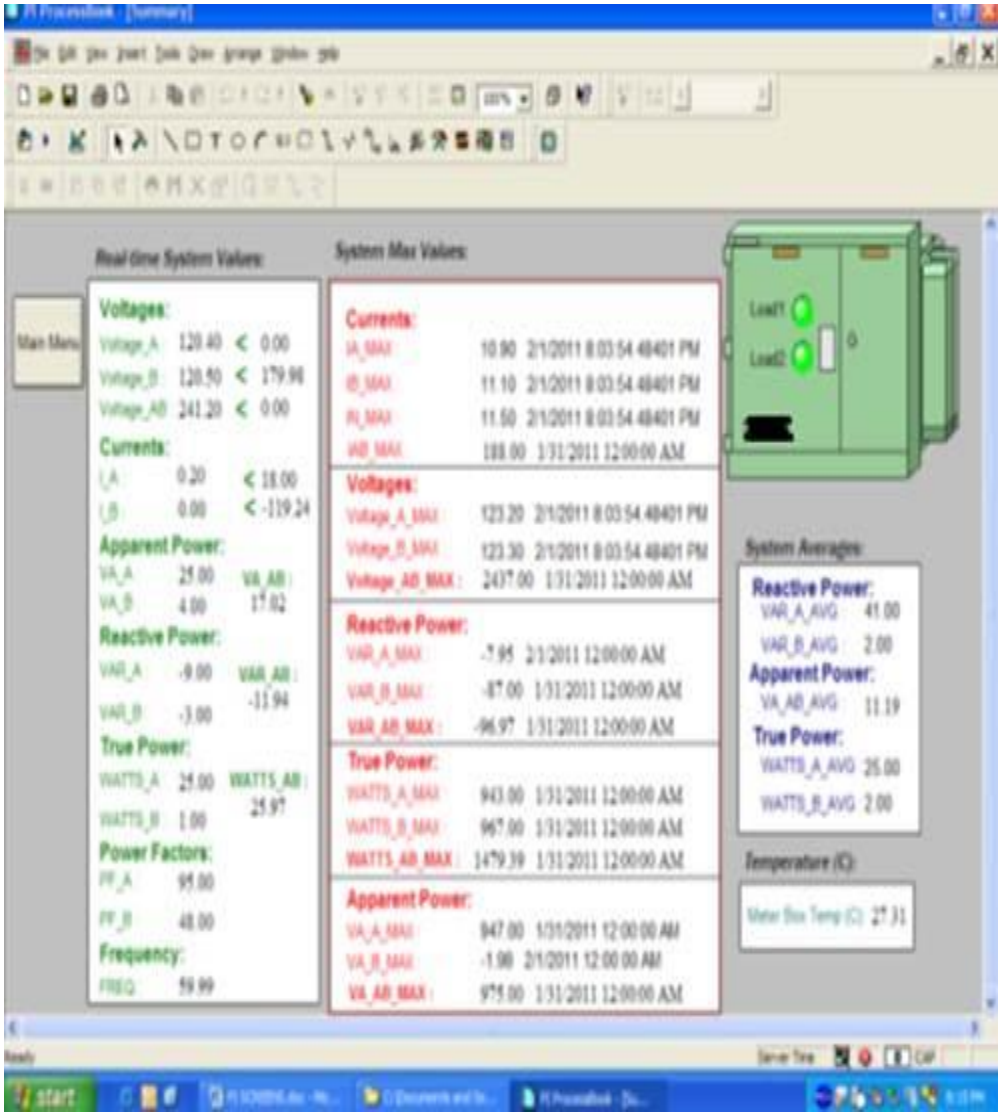
- Acquiring additional data from smart grid wireless devices
  - Fault Circuit Indicators
  - Aircraft warning light status
  - Smart Transformers





Smart Transformer EV Analytics





Gas Meter Event Processing

- Consume gas meter events for analysis
- Provide exceptions back to meter data management system
- Provided advice on implementation approach and sizing
- 900k meters, 6 events each, twice a day
- 5.4MM tags

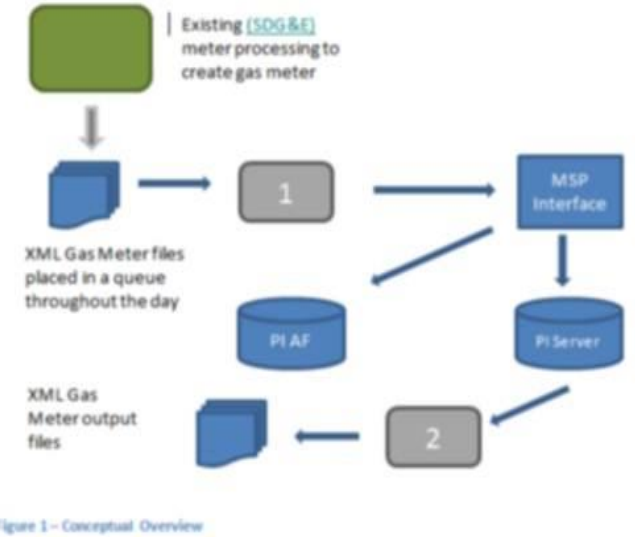


Figure 1 – Conceptual Overview

PI Server 2012 *Data Archive Sizing*

Please review and modify the values in yellow cells, sizing recommendations are shown in orange cells

PI Collective Size	2	members
Total Point Count	5,500,000	points
Average Point Sampling	43,500.00000	sec (0 Hz)
Data Retention Requirement	48	months
Measurement Data Type	int32	(32-bit precision)
Average Data Compression	90	% (10:1)
Estimated Snapshot Rate	126	events/sec
Estimated Event Size	7	bytes
Estimated Archiving Rate	13	events/sec

STORAGE		
Minimum Archive Size	10,750	MB
Recommended Archive Size	25	GB
Total Online Disk Space	200	GB
Estimated Archive Count	1	files/year
Estimated Archive Volume (per PI Collective member)	0	MB/hour
	0	GB/month

DISK I/O		
Minimum Disk Throughput	18	MB/sec
Minimum Disk Latency	10	IOPS*
Recommended Disk Throughput	20	MB/sec
Recommended Disk Latency	100	IOPS*

(*) See "KB Article #xxxxx" for details on how to evaluate IOPS

PI Interface Nodes	3	nodes
Active Client Applications	1	application
Average Query Interval	60	seconds
Average Query Range	8.0	hours
Average Points per Query	1,000	points
Estimated Query Rate	1	events/sec

PROCESSOR		
Minimum CPU Count	4	cores†
Recommended CPU Count	8	cores†

(†) Physical cores (not counting Hyper-Threading) or 100% allocated virtual cores

MEMORY		
Minimum RAM	32,250	MB
Recommended RAM	75	GB
Estimated Cache Capacity	163,880	hours
Estimated Cache Efficiency	100	%
Non-Cached Archive Reads	-	events/sec

NETWORK		
Minimum Bandwidth‡	10	Mbps
Recommended Bandwidth‡	100	Mbps

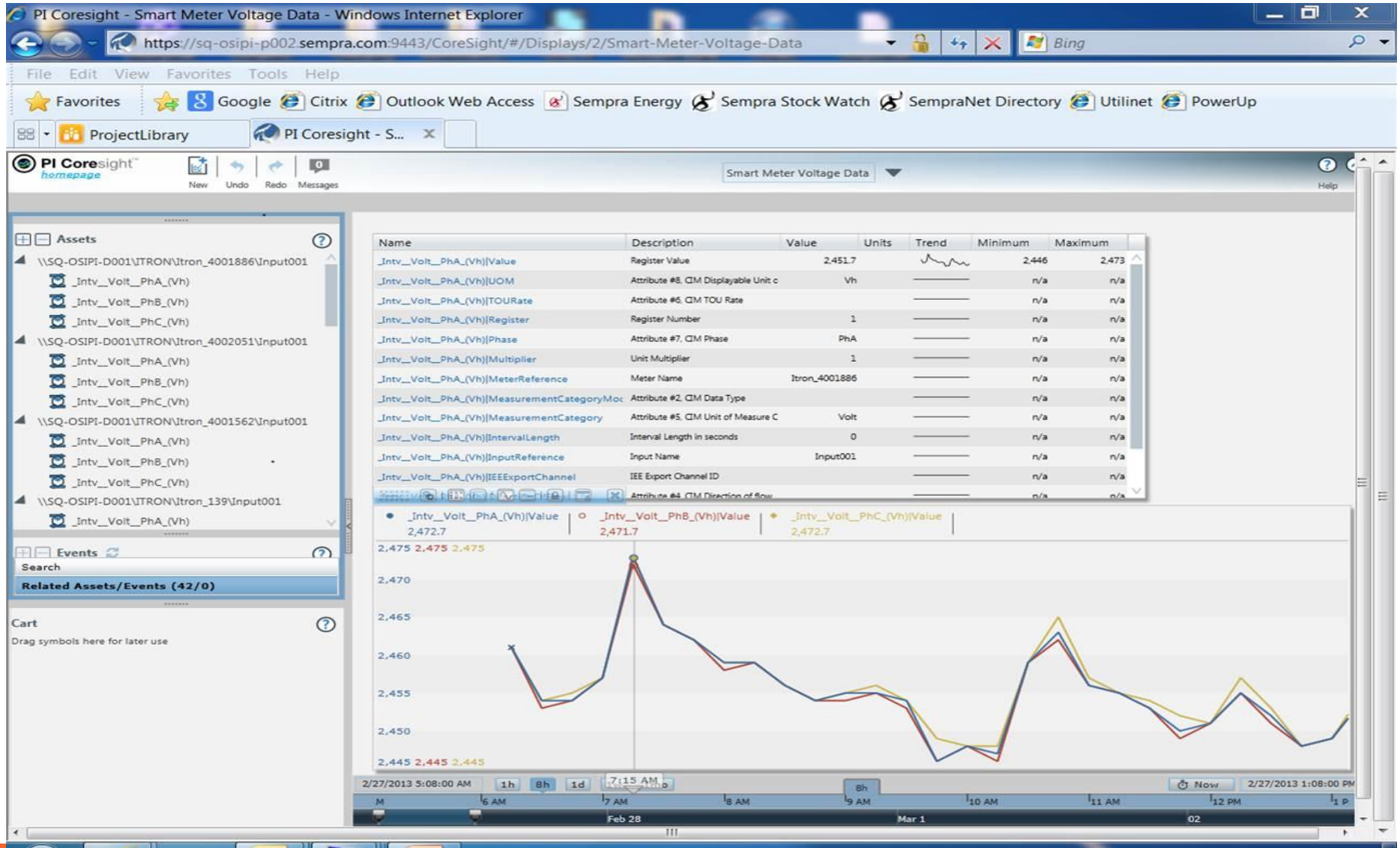
(‡) See "Buffer and Bandwidth Calculation" spreadsheet for latency considerations

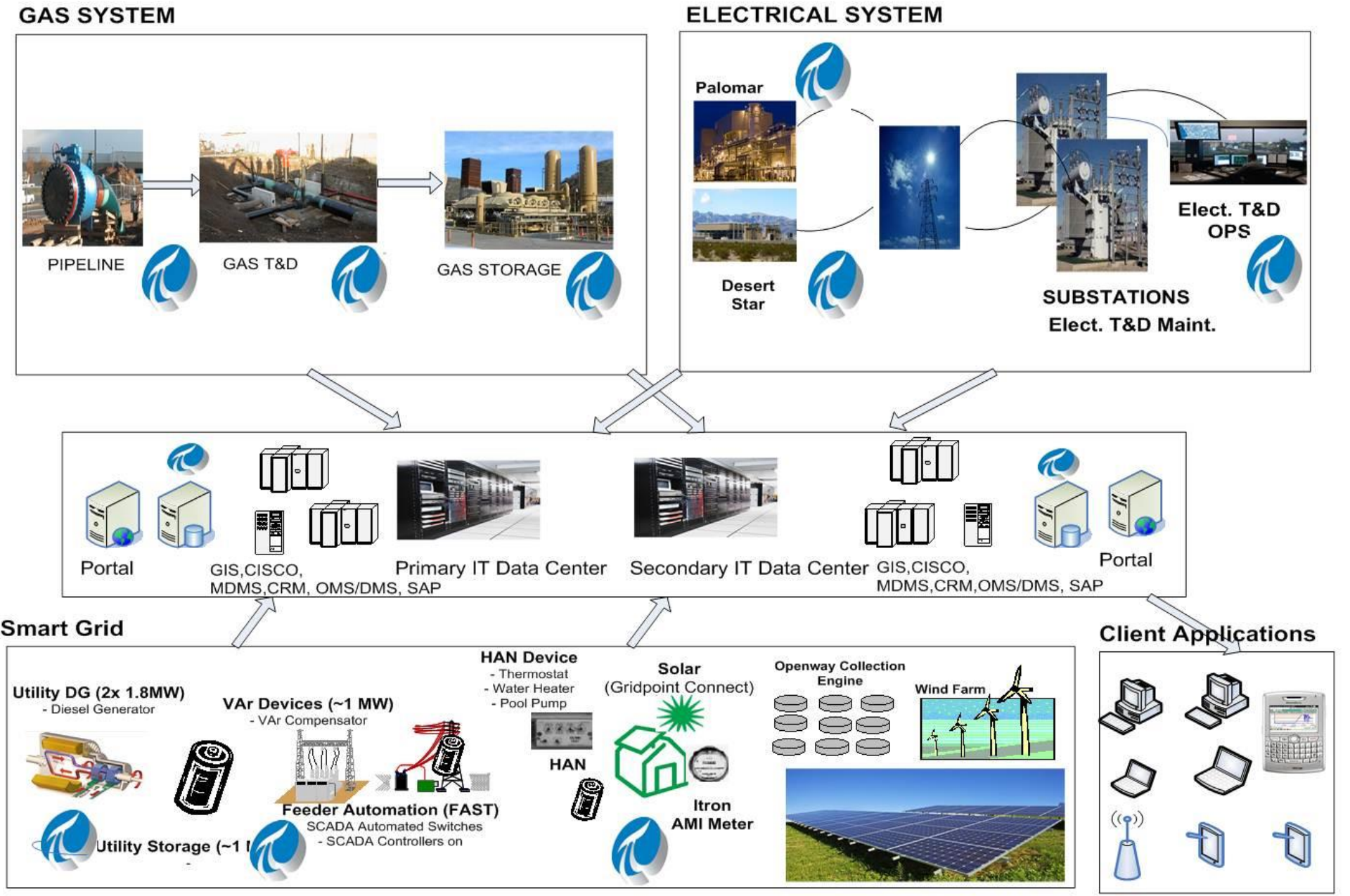
Non-Billing Smart Meter Data Analytics

- New subscriber interface to head-end system
- Collect instantaneous voltage levels
- Analyze voltage against upstream data
- Targeting PV and older circuits customers first
- CoE Provided project advice, architecture, sizing, etc.
- Developing production interface to head-end system
- Supports auto-creation of AF elements

configuration Date	2/2/2011	2/2/2011	2/24/2011	2/2/2011	6/19/2012	9/6/2012
Voltage Monitor						
Enable Voltage Monitor	True	True	False	True	True	True
Phase Selection	Phase A	Phase A	Phase A	Phase A	Phases A, B, C	Auto Detect
Interval Length	60 minutes	60 minutes	5 minutes	15 minutes	15 minutes	15 minutes
VoltHour Low Threshold (per interval)	93	93	80	93	93	93
VoltHour High Threshold (per interval)	107	107	120	107	107	107
RMS Volt Low Threshold	192	192	192	192	80%	80%
RMS Volt High Threshold	288	288	288	288	120%	120%
Instantaneous Voltage High/Low Alarm Latency	N/A	N/A	N/A	N/A	N/A	0 seconds

Smart Meter Data Analytics





Summary of EA Benefits

- PI System Strategic Expertise and Advice
- PI System Installs
- Interface Development
- PI System Monitoring
- PI Promotion and Training Events
- Removed Project Constraints for PI Adoption
- Expanded Organizational Capabilities with one Toolset

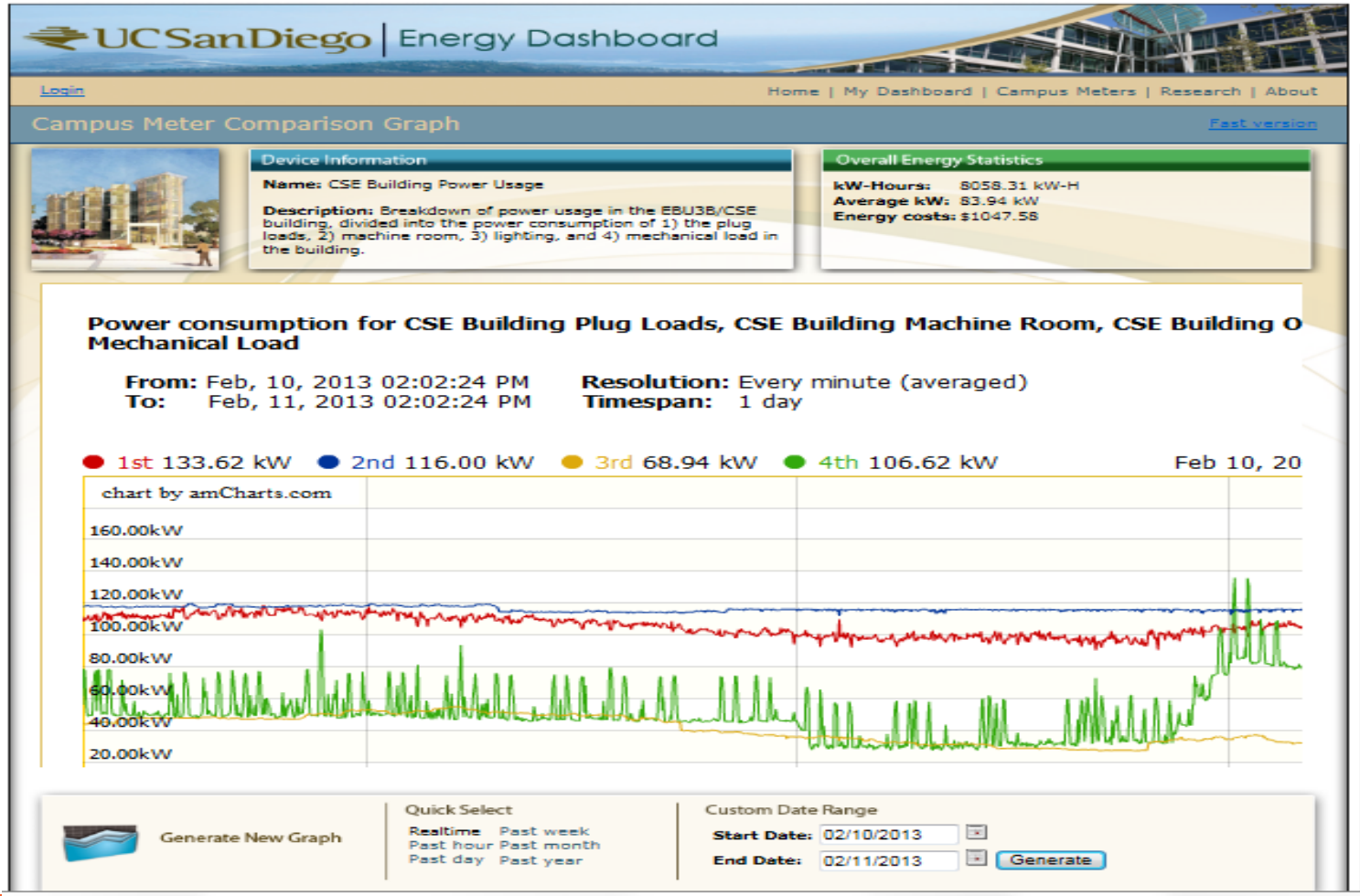
PI System for Microgrids Smart City

UCSD-University of California, San Diego Microgrid – The City in a City

- Internationally recognized microgrid
  - 28,000 students and 28,000 faculty and staff
    - Rated 7th best public University in Nation by U.S. News
    - Jacobs School of Engineering 4th in Bioengineering
  - Peak load ~45 MW
  - Self Generation 30 MW
  - Solar PV ~1.5 MW
  - Fuel Cell 2.8 MW
  - Battery systems
    - Second life (60 kWh)
    - Peak shifting (30 kW/30 kWh)
    - 3 MW/6 MWH in Q3 2012

You Can't Manage What You Don't Measure

http://energy.ucsd.edu/campus/graphset.php?setID=2&mode=pastday



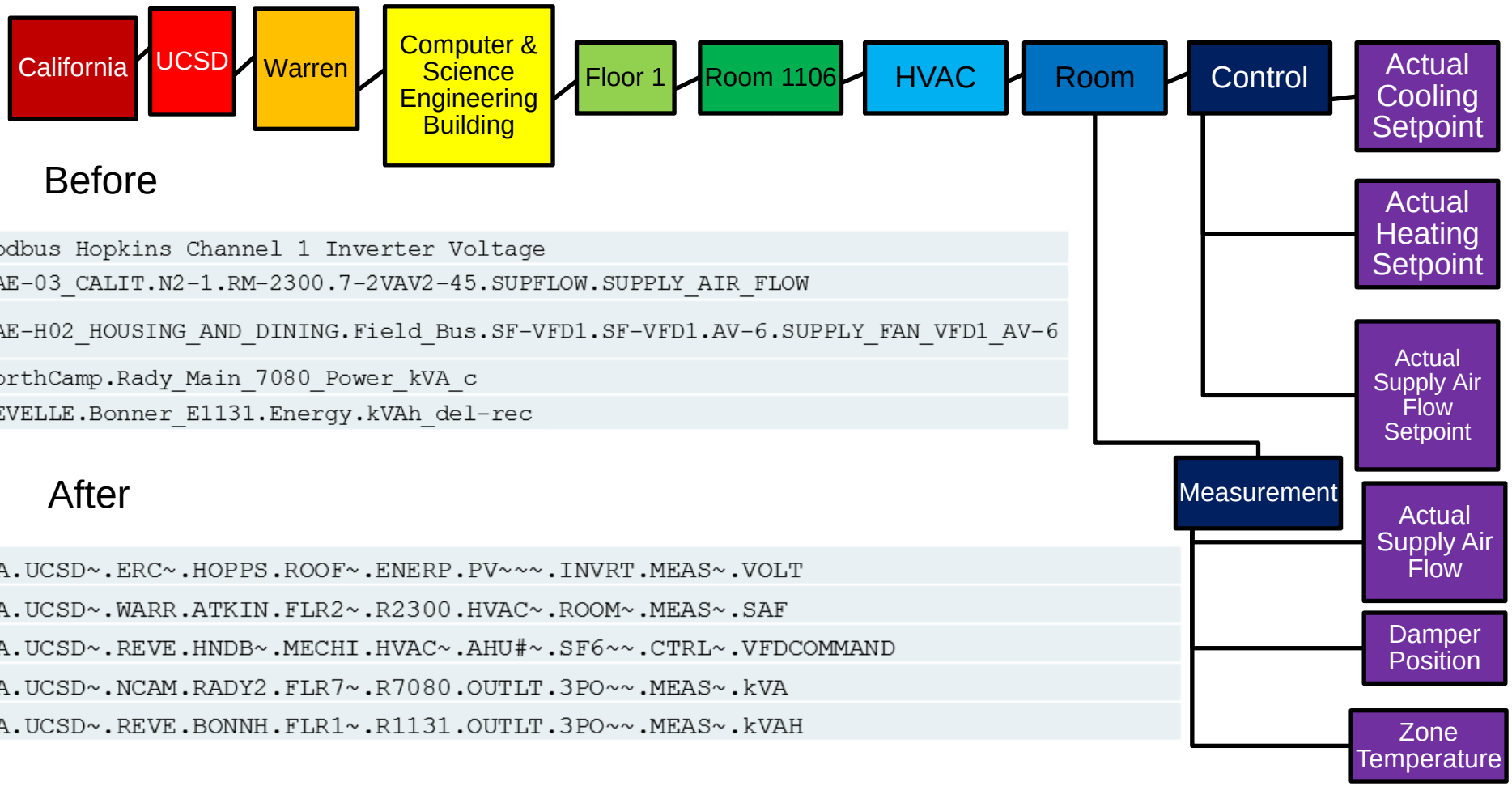
KEY PERFORMANCE INDICATOR

- **Measures performance of a building**
- **Annual energy per square foot**
- Can include other variables:
  - Occupancy
  - Building type
  - Direction the windows face
  - Energy source
- Comfort KPI can include:
  - Amount of air flow
  - Zone temperature
  - Quality of air (CO_2)

Why work on Building

- As of 2010, the DoE reported that building energy consumption represents **41.1% of the U.S. Primary Energy Consumption** which was greater than the industrial and transportation sectors
- A small improvement in building HVAC efficiency can result in large reduction in carbon emissions and lower costs of operations.
- Building might be useful “control” devices in local area power systems, especially to help compensate for solar PV and EV charging system intermittency

Naming Structure



Before

```
Modbus Hopkins Channel 1 Inverter Voltage
NAE-03_CALIT.N2-1.RM-2300.7-2VAV2-45.SUPFLOW.SUPPLY_AIR_FLOW
NAE-H02_HOUSING_AND_DINING.Field_Bus.SF-VFD1.SF-VFD1.AV-6.SUPPLY_FAN_VFD1_AV-6
NorthCamp.Rady_Main_7080_Power_kVA_c
REVELLE.Bonner_E1131.Energy.kVAh_del-rec
```

After

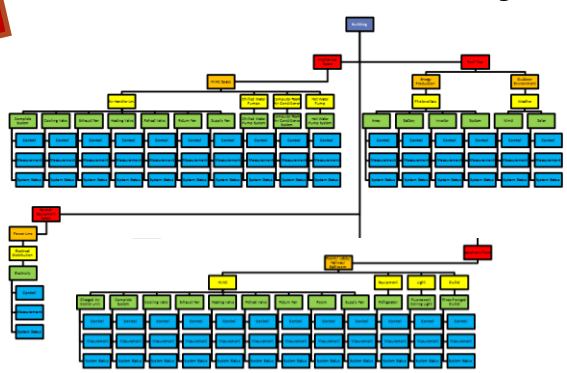
```
CA.UCSD~.ERC~.HOPPS.ROOF~.ENERP.PV~~~.INVRT.MEAS~.VOLT
CA.UCSD~.WARR.ATKIN.FLR2~.R2300.HVAC~.ROOM~.MEAS~.SAF
CA.UCSD~.REVE.HNDB~.MECHI.HVAC~.AHU#~.SF6~~.CTRL~.VFDCOMMAND
CA.UCSD~.NCAM.RADY2.FLR7~.R7080.OUTLT.3PO~~.MEAS~.kVA
CA.UCSD~.REVE.BONNH.FLR1~.R1131.OUTLT.3PO~~.MEAS~.kVAH
```

Semantic Auto-discovery Tool

Problem: Same data type given different names due to different naming conventions used by field engineers and/or unknown data type

ACD7-1-SP
ACLG_Setpoint
ACLG-SP
ACLG-STPT
ACTCLGSP
ACTCLG-SP
ACTCLG-STPT
ACT-CSP
ADF21

Develop "gold standard" naming convention hierarchy:

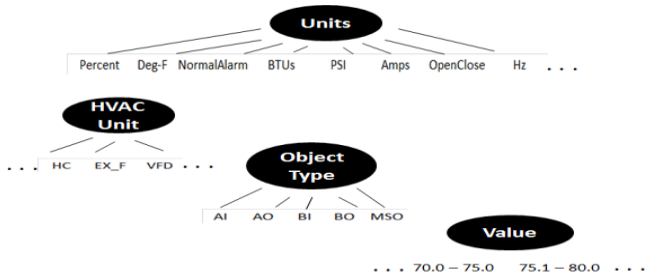


Label subset of data and existing features for supervised learning:

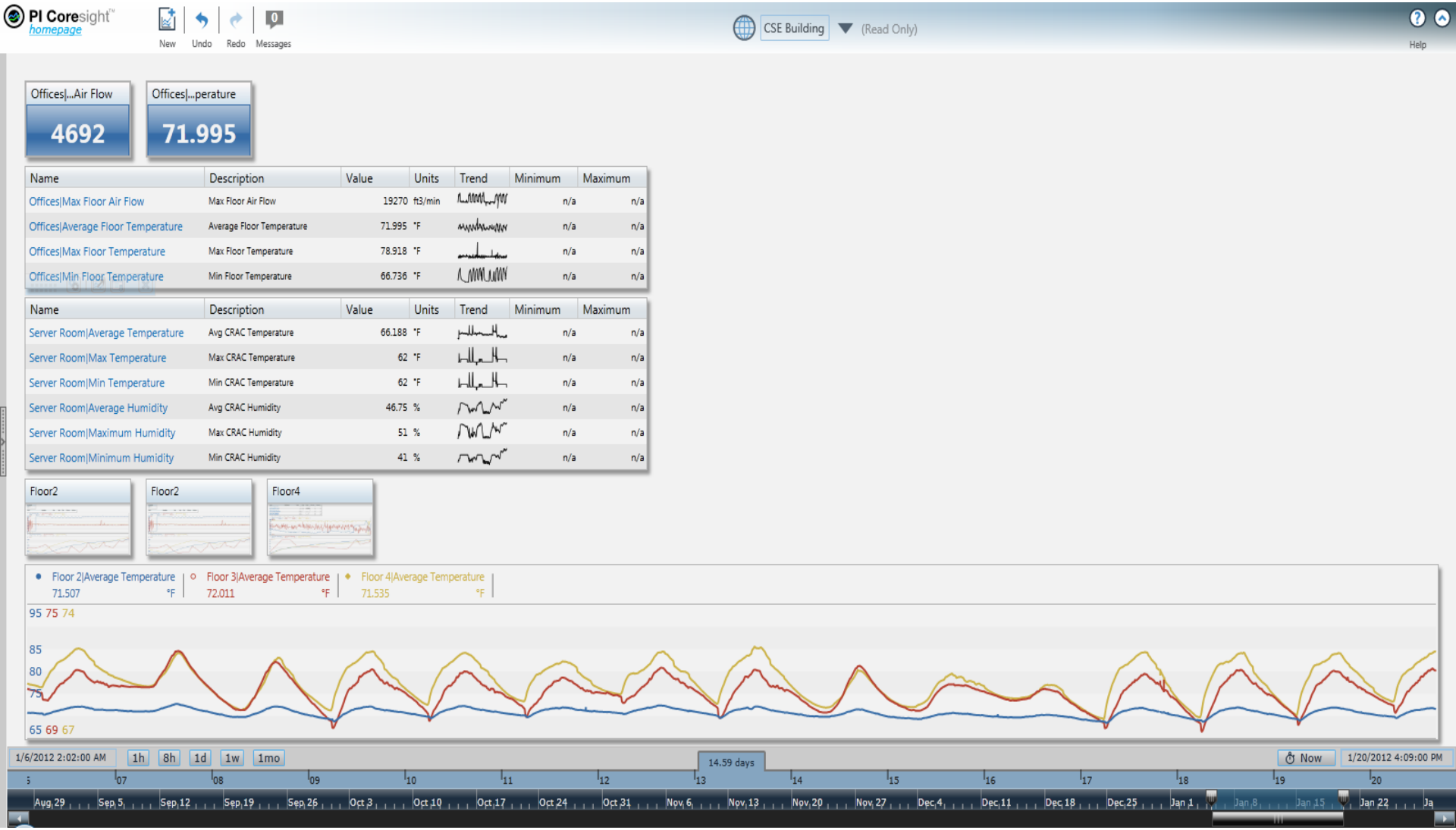
Name	Obj. Type	Value	Units	ANA-Precision
DX-080.HW-DP1	AI	8.710938	PSI	1
DX-080.HW-DP2	AI	9.289063	PSI	1
DX-080.MTWR-T	AI	156	Deg-F	1
UNT-088.ZN-T	AI	74.1384	Deg-F	1
UNT-088.DA-T	AI	54.88446	Deg-F	1
VND-075.FREQ-OUTPUT	AI	48.2	Hz	0
VND-075.CURRENT	AI	17.6	Amps	1
UNT-070.ZN-T	AI	74.63138	Deg-F	1
UNT-070.DA-T	AI	74.39786	Deg-F	1
VND-082.CHWS-T	AI	43.86	Deg-F	1
VND-082.HTHWS-T		307.1	Deg-F	1
VND-082.CHWR-T		58.74	Deg-F	1

⋮

Add features and use machine learning algorithms combined with edit distances and naming convention to create rules to predict data type and create tag and XML output:

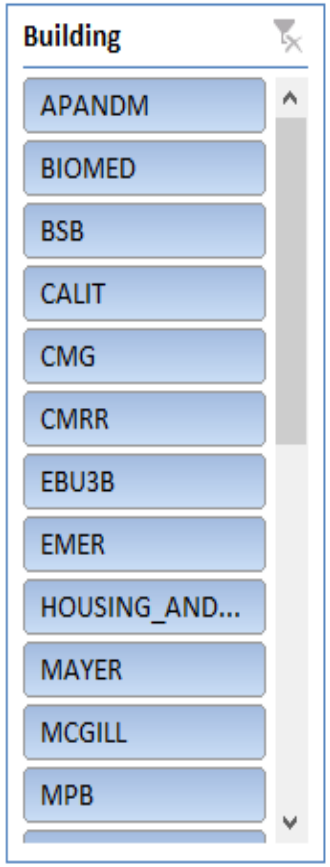


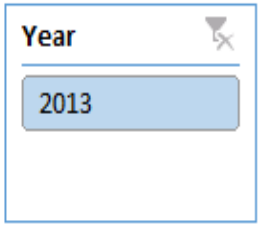
Computer Science & Engineering Building

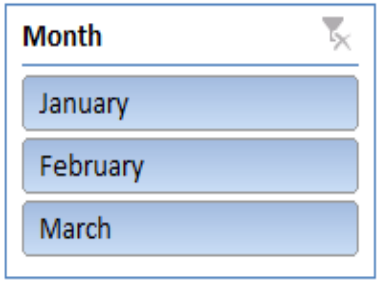


Building Carbon Emission Analytics with PowerPivot

Carbon Emission Analytics



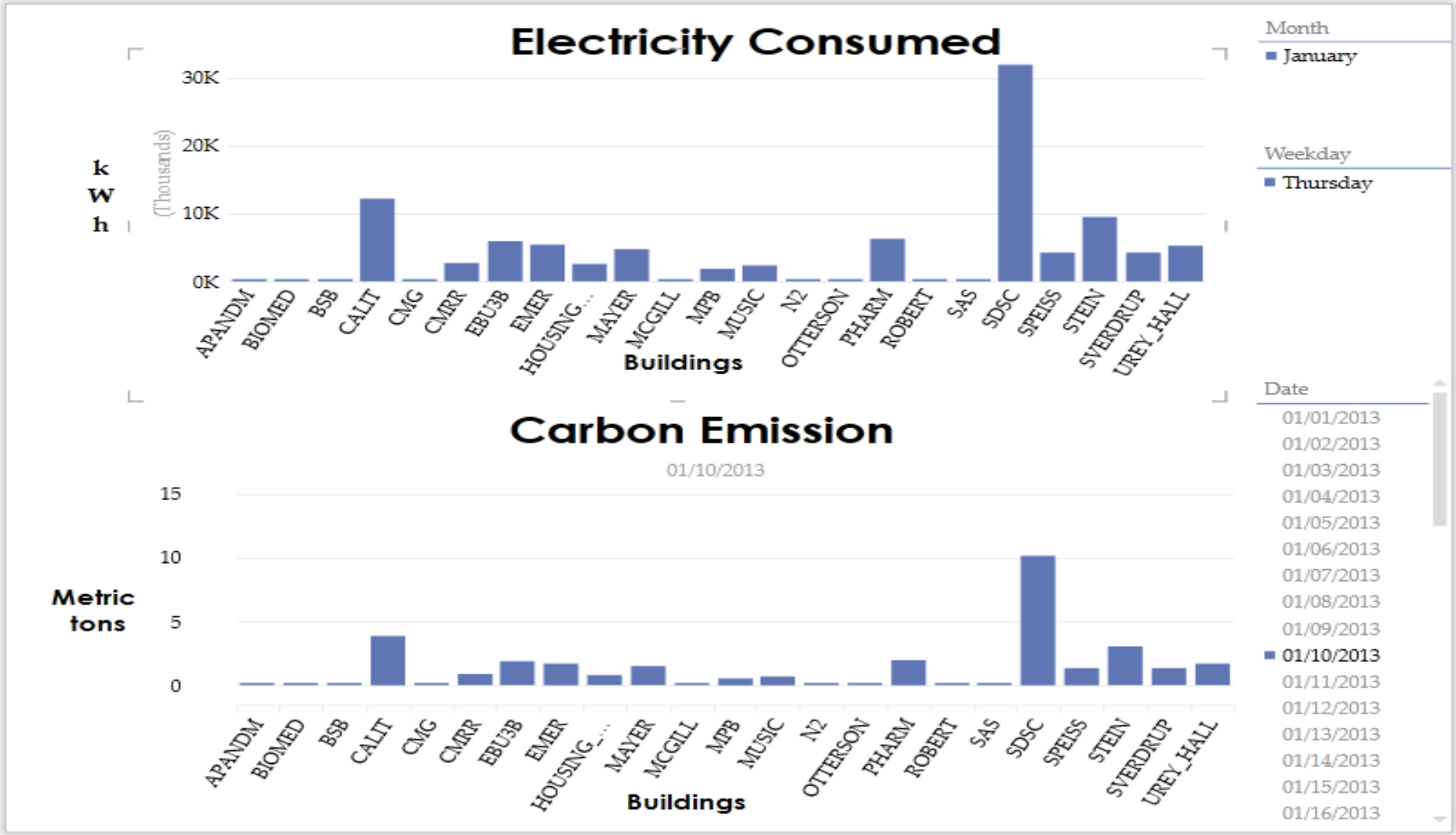




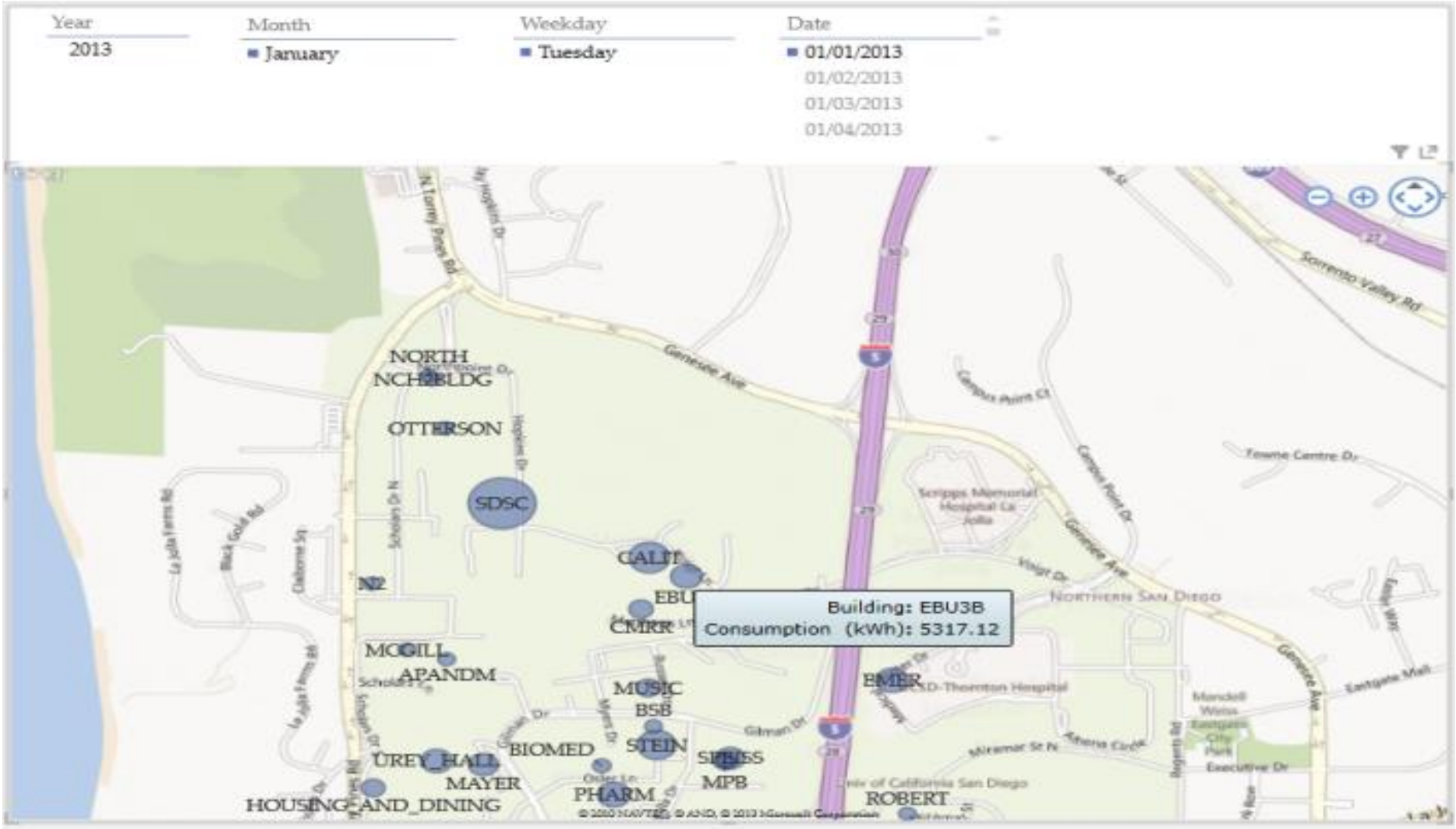
Consumption (kWh)	Month		
Buildings	January	February	March
SDSC	999756.69	679314.01	988391.06
CALIT	371355.44	268336.22	390315.80
STEIN	280989.98	179877.12	253186.95
PHARM	200682.70	138774.86	194759.47
EBU3B	177791.83	125675.84	123449.52
UREY_HALL	164861.62	116292.59	112867.04
EMER	160483.07	114479.64	155474.04
MAYER	138590.93	93285.93	133956.15
SPEISS	133037.01	117488.61	138455.10
SVERDRUP	121428.05	88993.14	135863.54

Carbon Emission (Metric tons)	Month		
Buildings	January	February	March
SDSC	317.44	215.69	313.83
CALIT	117.91	85.20	123.93
STEIN	89.22	57.11	80.39
PHARM	63.72	44.06	61.84
EBU3B	56.45	39.90	39.20
UREY_HALL	52.35	36.92	35.84
EMER	50.96	36.35	49.37
MAYER	44.00	29.62	42.53
SPEISS	42.24	37.30	43.96
SVERDRUP	38.56	28.26	43.14

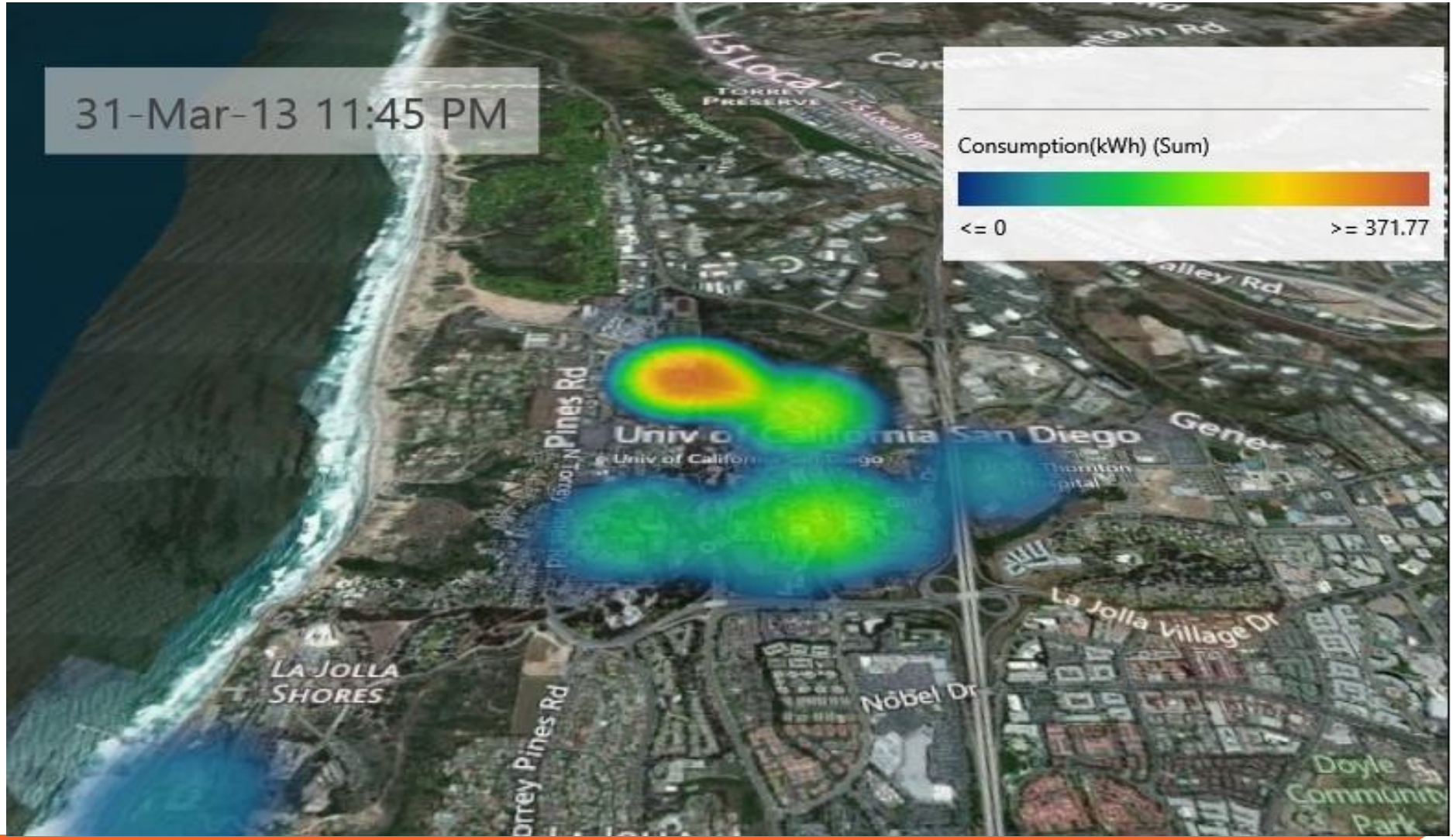
Building Carbon Emission Analytics with Power View



Building Carbon Emission Analytics with Bing Maps



Building Energy Consumption with GeoFlow Heat Map



Smart City (San Diego)

Windows 8
"Prius" dashboard

PI 2012 + SQL 2012 EE +
SharePoint 2013

PI Visualization (DL, WP, CS, PB)

AF, Asset Based Analytics

PowerView, PowerPivot, GeoFlow

Azure IaaS (VM)

Power View
Business Insight "drill down"

Azure PaaS

PI Cloud Connect

Azure PaaS

PI Cloud Connect

SDSU

PI

UCSD

San Diego Gas & Electric (SDG&E)

Downtown Buildings

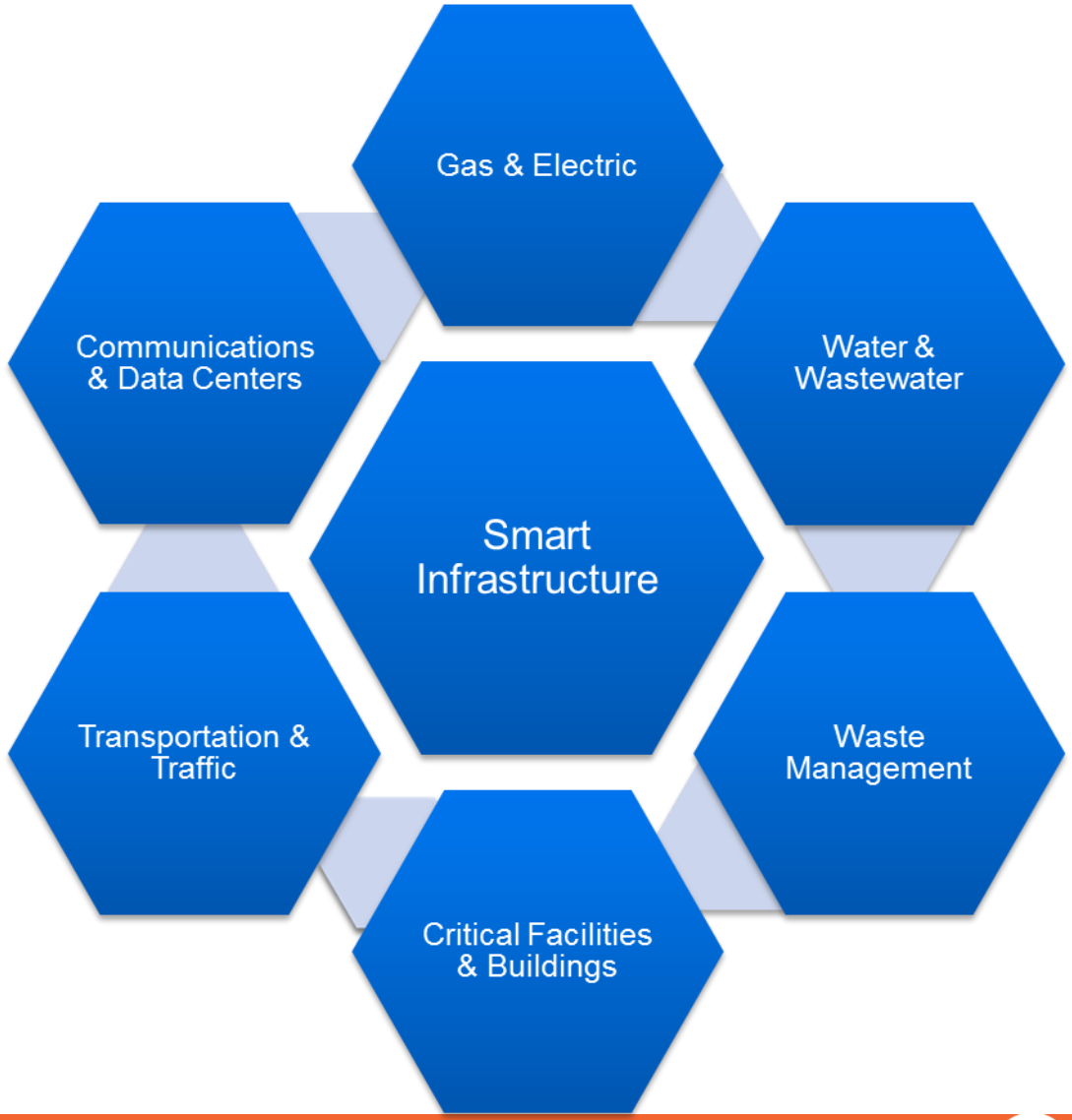
Pipeline Interface

Pipeline Interface

Pipeline Interface

Why does a City need a Data Infrastructure?

- A common data infrastructure that connects all of the various physical assets/infrastructures
  - Electrical
  - Gas
  - Water
  - Transportation & Traffic
  - Critical Facilities
  - Communications
  - Buildings



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Director, Industry and Market Principals

OSIsoft, LLC

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