An End2End (E2E) Operationalized Pipeline for Predictive Analysis for the Intelligent Grid

Presented by

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Agenda

- China Southern Power Grid (CSG) Introduction
- Electric Power Research Institute, CSG Introduction
- USTDA (United States Trade & Development Agency) Funded Smart Grid Project Introduction
- Project Plan and Milestones
- Implementation and Results
- Microsoft Azure Machine Learning Predictive Analysis
- Future Plans

Introduction of China Southern Grid

- China Southern Power Grid Co. Ltd (CSG) was established on 29th December, 2002.
- CSG covers Guangdong, Guangxi, Yunnan, Guizhou and Hainan provinces. Also it is closely connected with Hong Kong, Macao and other areas related. It supports electricity to 230 million people within 1.02 million square kilometers.
- In 2012, the CSG has generated electricity for 190,000 MW, among which the clean energy constituted 43%. The max load was 120,000 MW. The total electricity consumption was 839.6 million MWH.
- CSG has been one of the global top 500 enterprises in nine consecutive years; ranked the 134th in 2013.

Introduction of China Southern Grid (cont'd)

CSG: The AC/DC interconnected Power Grid with long distance, large-capacity electricity transmission.

◆ CSG has 13 channels transmitting electricity from the West to the East with 8 AC and 5 DC channels.

◆ Every transmission channel is around 1,000 km, and the West-to-East span is nearly 2,000 km.

◆ The 500 kV AC and DC parallelly hybrid Grid, with 99 substations, 354 transmission lines, has very complicated operating features.

◆ In 2012, the max electricity transmitted from the West to Guangdong Province was around 24,430 MW.

Introduction of EPRI, CSG

History of EPRI

2004 Technology Research Centre , CSG

2007 Electric Power Technology Research Centre

2007 National Certified Enterprise Technical Center

2009 National Energy Large Grid Technology Research(Test) Center

2010 Electric Power Research Institute, CSG

- The Southern Electric Power Research Institute (SEPRI), is a subsidiary of China Southern Power Gird, established on the basis of CSG Technology Research Centre on 6th August, 2010.
- The main business of SEPRI include: science research, technology support & consulting, and project integration.
- SEPRI provides technology support for the science research, grid planning, system operation and market services, etc.

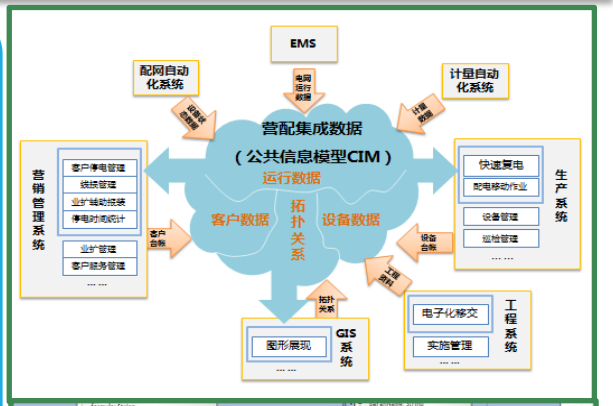
Project Introduction

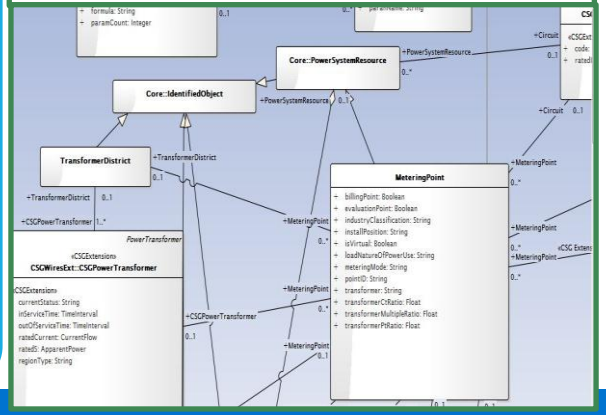
Integration Platform of distribution and utilization information

◆ Developing the integration platform of distribution and utilization information in Guangzhou, Shenzhen and other cities since 2009.

◆ The platform integrating the information from EMS, GIS, DMS, AMS, MS (Market System), etc. to eliminate the information islands and share the information resources.

◆ The platform establishing the Enterprise Common Information Model (ECIM) based on IEC61968 and IEC61970.





Project Introduction (cont'd)

Integration Platform of distribution and utilization information

◆ Based on the integration platform of distribution and utilization information, developing advanced business applications, such as customer service monitoring, power outage analysis, line loss analysis, power quality analysis, etc.

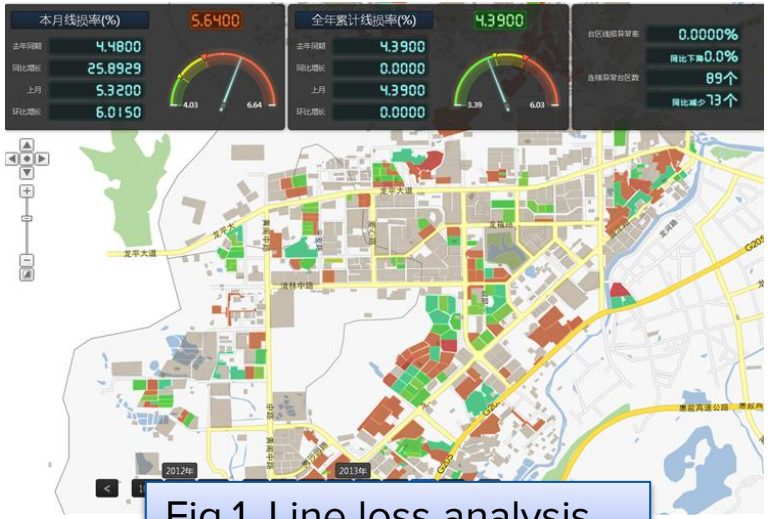


Fig.1 Line loss analysis

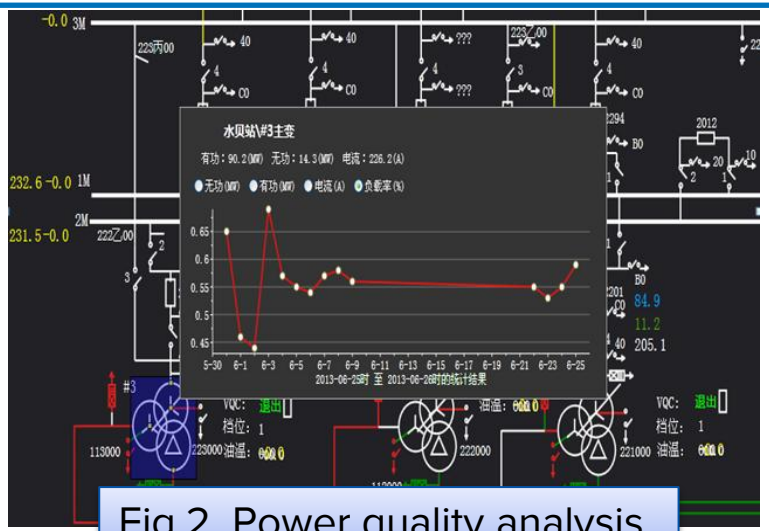


Fig.2 Power quality analysis

USTDA Funded Smart Grid Project

- Applied for US Trade & Development Agency Grant - September, 2012
- OSIsoft awarded - April, 2013
- Contract signed - December, 2013
- Project kick-off meeting - February, 2014

Project Plan and Milestones

- Identified data sources and system installation (Apr, 2014)
- SISCO conducted CIM training and CSG CIM profile creation workshop (June, 2014)
- Collected and backfilled data from one city (Aug, 2014)
- Used SISCO PI CIM Adapter to create CIM in Asset Framework (Sept, 2014)
- Defined use cases (Oct, 2014)
- Worked with Microsoft on Azure Machine Learning for forecasting (Dec, 2014)
- Completed use cases (March, 2015)

Objective - Energy Efficiency Analysis and Forecast

- Provide big data analysis about industrial customer energy usage and energy profile
- Provide energy efficiency benchmark and forecast
- Integrate with GIS based visualization
- Provide guidance for energy efficiency improvement

Ultimate Goal - Advanced Analysis and Forecast

- Load analysis and forecast (including weather condition, temperature, etc.)
- Total energy consumption analysis and classification
- Period energy and cost analysis (peak, off peak and normal period)
- Define energy efficiency KPI
- Equipment operation condition analysis
- Industry production time suggestion
- Market and sales suggestion (different tariff /price analysis)

Distribution City-Level End-to-End

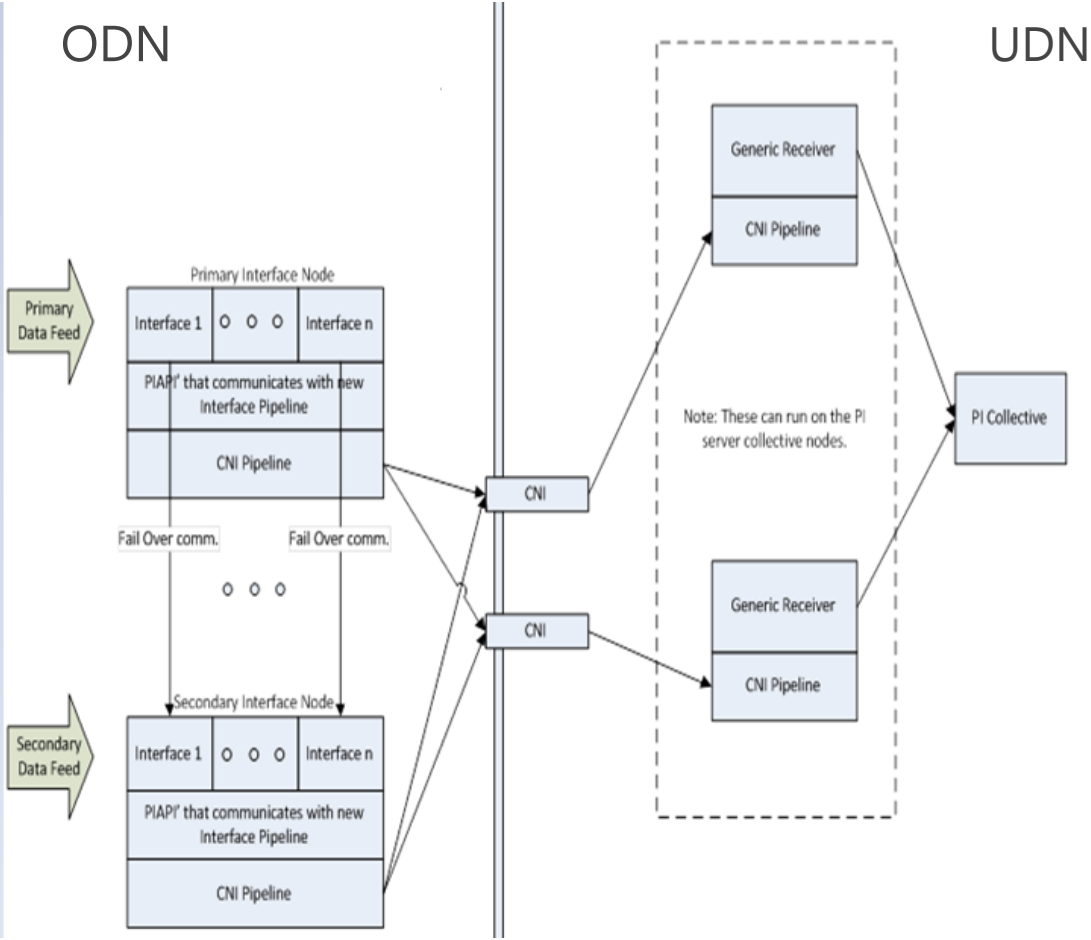
- From a typical 220kV substation, all the way down (110kV-10kV) to its commercial and industrial customer meters
- 80% industrial and commercial, 20% residential
- Two years of data
- The entire city has about 71,360 distribution transformers

Use Cases

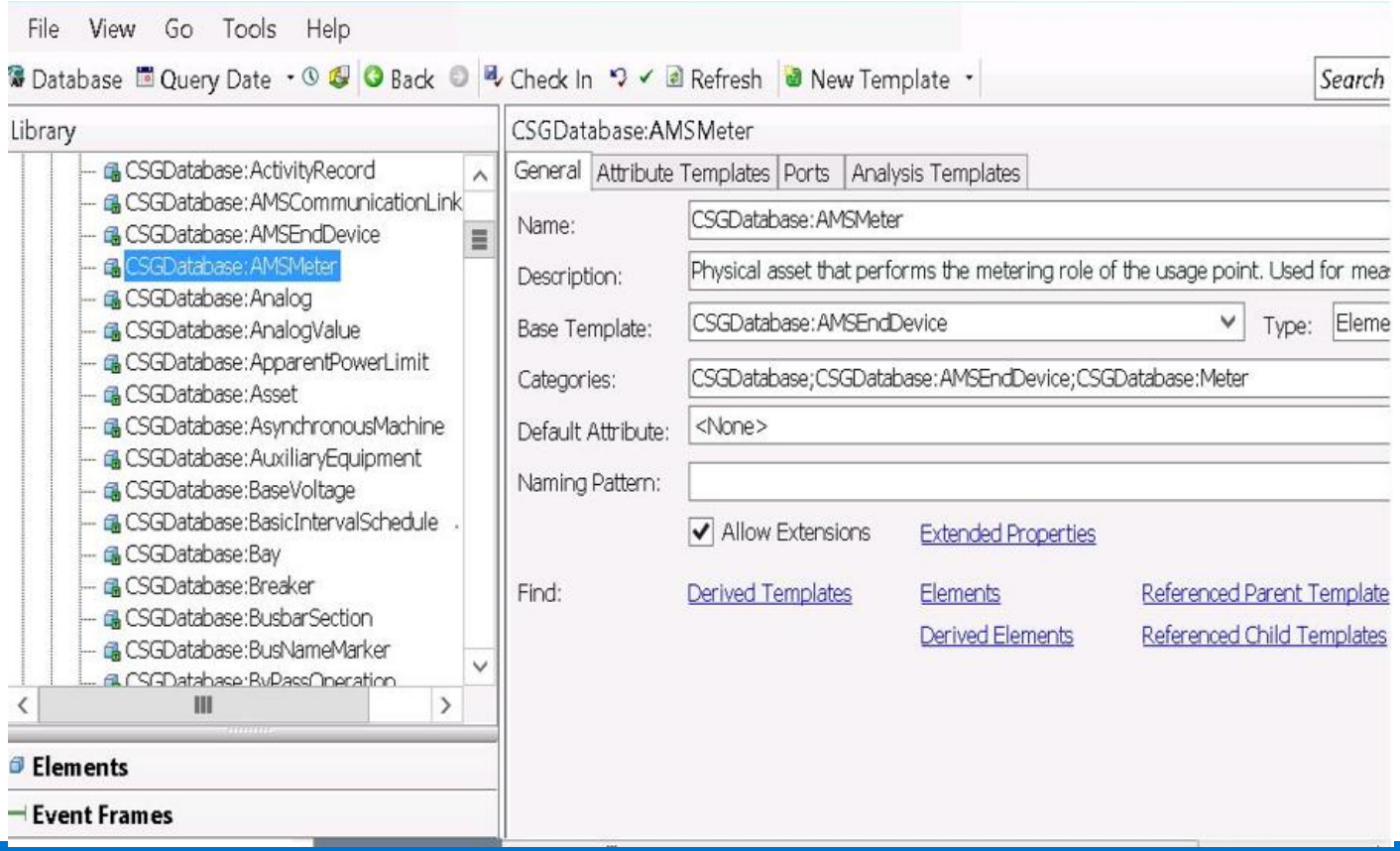
- Distribution loss calculation and analysis
- Distribution loading analysis
- Distribution reliability indexes calculation and analysis (SAIDI, SAIFI, CAIDI, CAIFI, etc.)
- Customer energy efficiency analysis and prediction
- Customer energy consumption behavior analysis and load forecasting

Security

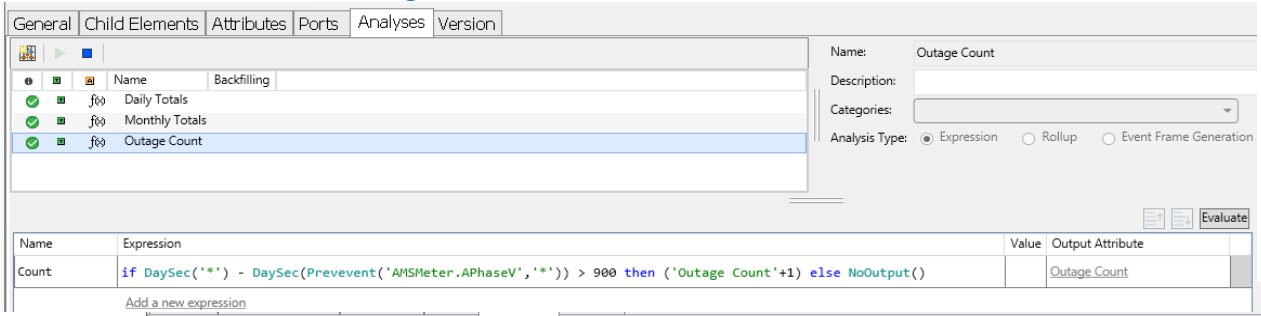
- PI CNI (China Network Isolator)
- Level I (Operation Data Network)
- Level II (Utility Data Network)
- PI HA (High Availability)
- WIS (Windows Integrated Security) or AD
- DMZ to Cloud



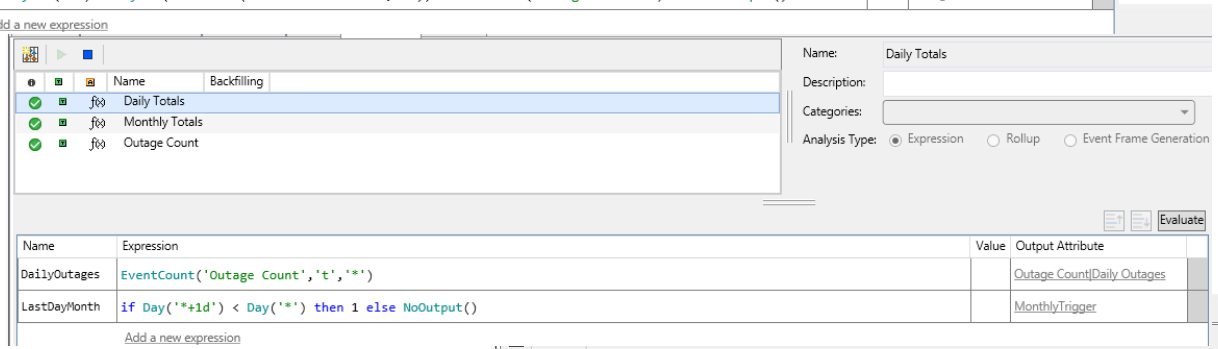
Meter CIM model in Asset Framework (AF)



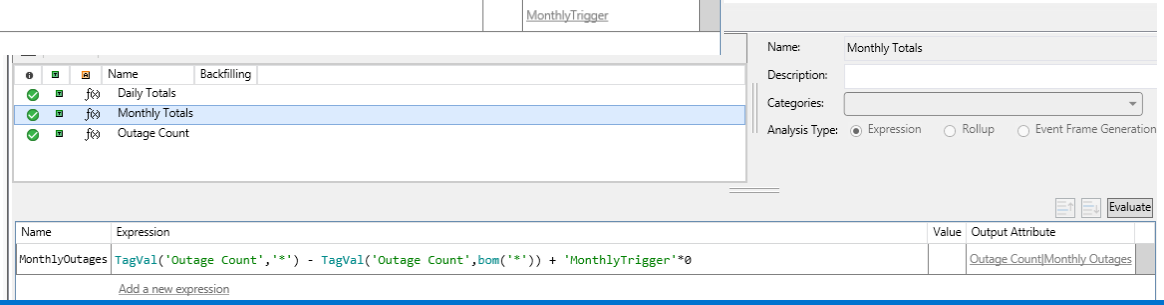
Asset Analytics



Outage Count



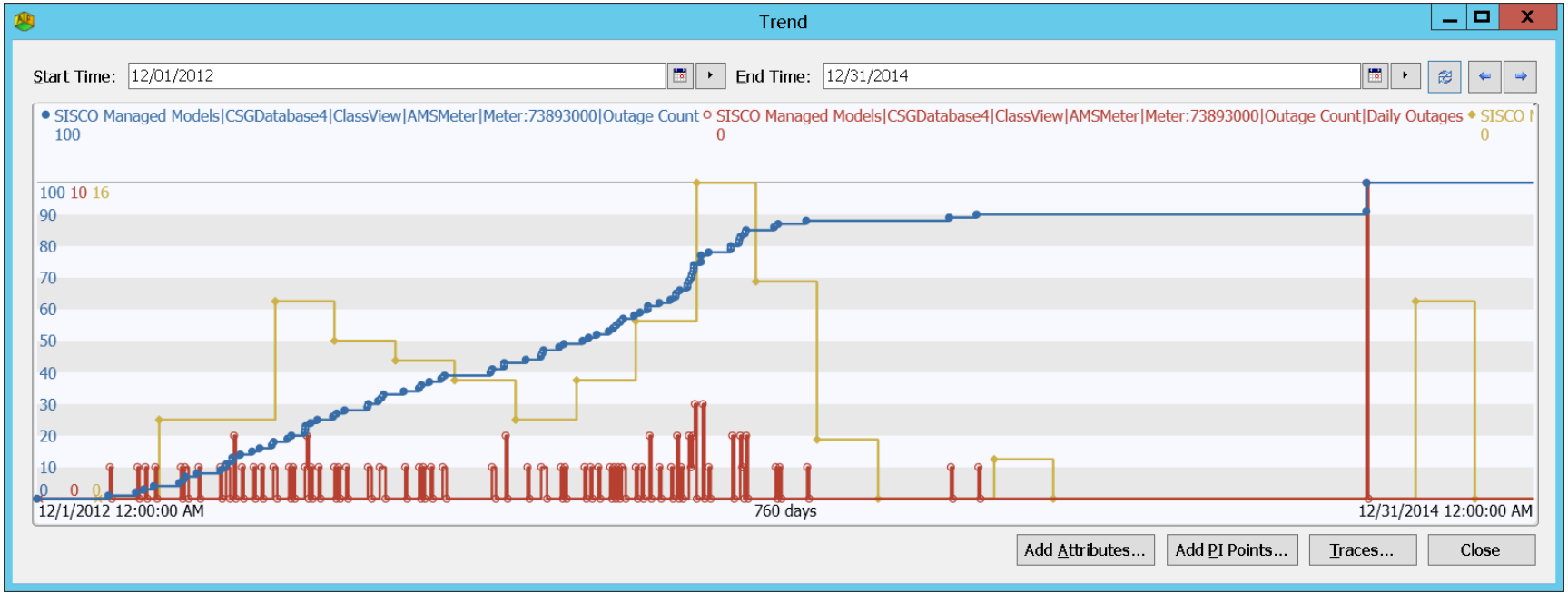
Daily Outage Totals



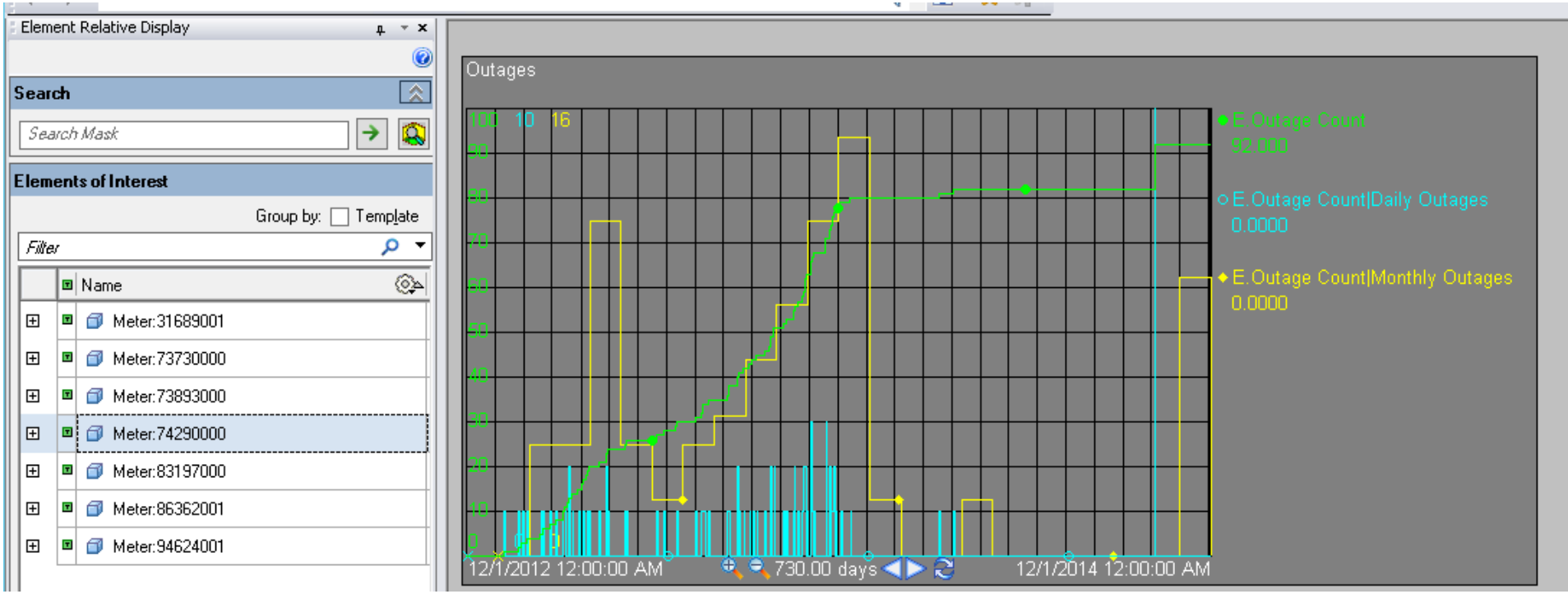
Monthly Outage Totals

Trend Outage Counters

Asset Analytics: Aggregated for Daily and Monthly Outages



Outage Calculation and Analysis



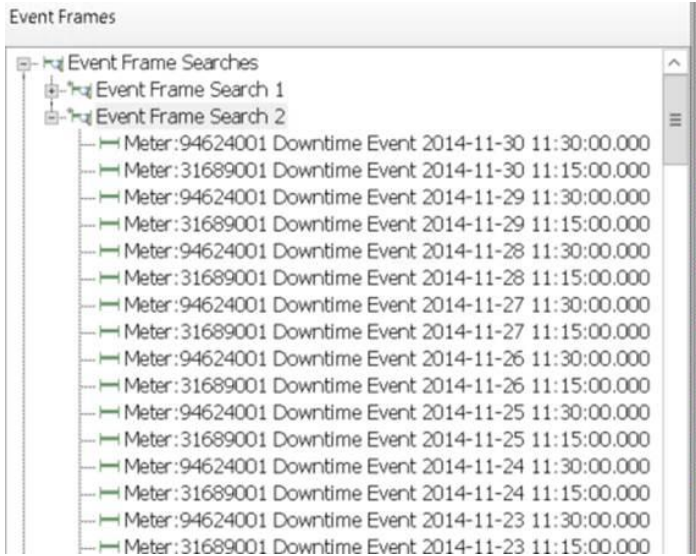
Event Frames (EF)

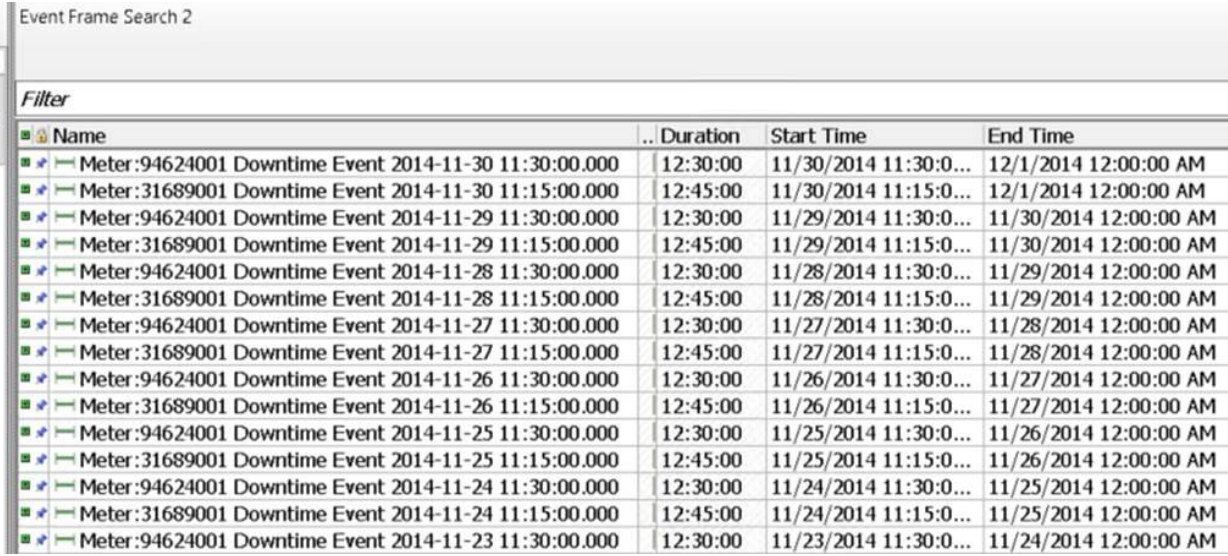
- Trigger Start Condition

Name	Expression	Value
StartTrigger	TagVal('Outage Count','*') - TagVal('Outage Count',PrevEvent('Outage Count','*	

- Event Attributes
  - Duration (Start and End Time)
  - Cause
  - Calculations related to Outage

EF for Meter Outages

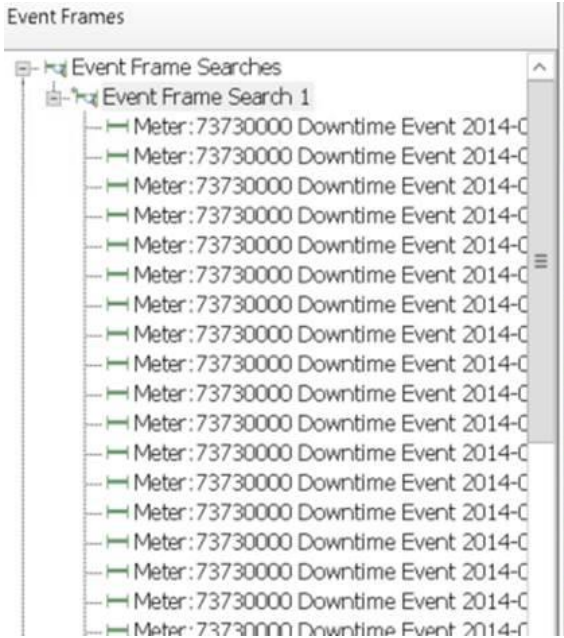




Name	Duration	Start Time	End Time
Meter:94624001 Downtime Event 2014-11-30 11:30:00.000	12:30:00	11/30/2014 11:30:0...	12/1/2014 12:00:00 AM
Meter:31689001 Downtime Event 2014-11-30 11:15:00.000	12:45:00	11/30/2014 11:15:0...	12/1/2014 12:00:00 AM
Meter:94624001 Downtime Event 2014-11-29 11:30:00.000	12:30:00	11/29/2014 11:30:0...	11/30/2014 12:00:00 AM
Meter:31689001 Downtime Event 2014-11-29 11:15:00.000	12:45:00	11/29/2014 11:15:0...	11/30/2014 12:00:00 AM
Meter:94624001 Downtime Event 2014-11-28 11:30:00.000	12:30:00	11/28/2014 11:30:0...	11/29/2014 12:00:00 AM
Meter:31689001 Downtime Event 2014-11-28 11:15:00.000	12:45:00	11/28/2014 11:15:0...	11/29/2014 12:00:00 AM
Meter:94624001 Downtime Event 2014-11-27 11:30:00.000	12:30:00	11/27/2014 11:30:0...	11/28/2014 12:00:00 AM
Meter:31689001 Downtime Event 2014-11-27 11:15:00.000	12:45:00	11/27/2014 11:15:0...	11/28/2014 12:00:00 AM
Meter:94624001 Downtime Event 2014-11-26 11:30:00.000	12:30:00	11/26/2014 11:30:0...	11/27/2014 12:00:00 AM
Meter:31689001 Downtime Event 2014-11-26 11:15:00.000	12:45:00	11/26/2014 11:15:0...	11/27/2014 12:00:00 AM
Meter:94624001 Downtime Event 2014-11-25 11:30:00.000	12:30:00	11/25/2014 11:30:0...	11/26/2014 12:00:00 AM
Meter:31689001 Downtime Event 2014-11-25 11:15:00.000	12:45:00	11/25/2014 11:15:0...	11/26/2014 12:00:00 AM
Meter:94624001 Downtime Event 2014-11-24 11:30:00.000	12:30:00	11/24/2014 11:30:0...	11/25/2014 12:00:00 AM
Meter:31689001 Downtime Event 2014-11-24 11:15:00.000	12:45:00	11/24/2014 11:15:0...	11/25/2014 12:00:00 AM
Meter:94624001 Downtime Event 2014-11-23 11:30:00.000	12:30:00	11/23/2014 11:30:0...	11/24/2014 12:00:00 AM

EF Showing Outage Duration

Drill down: meter *73730000* which is part of Feeder *14265073*

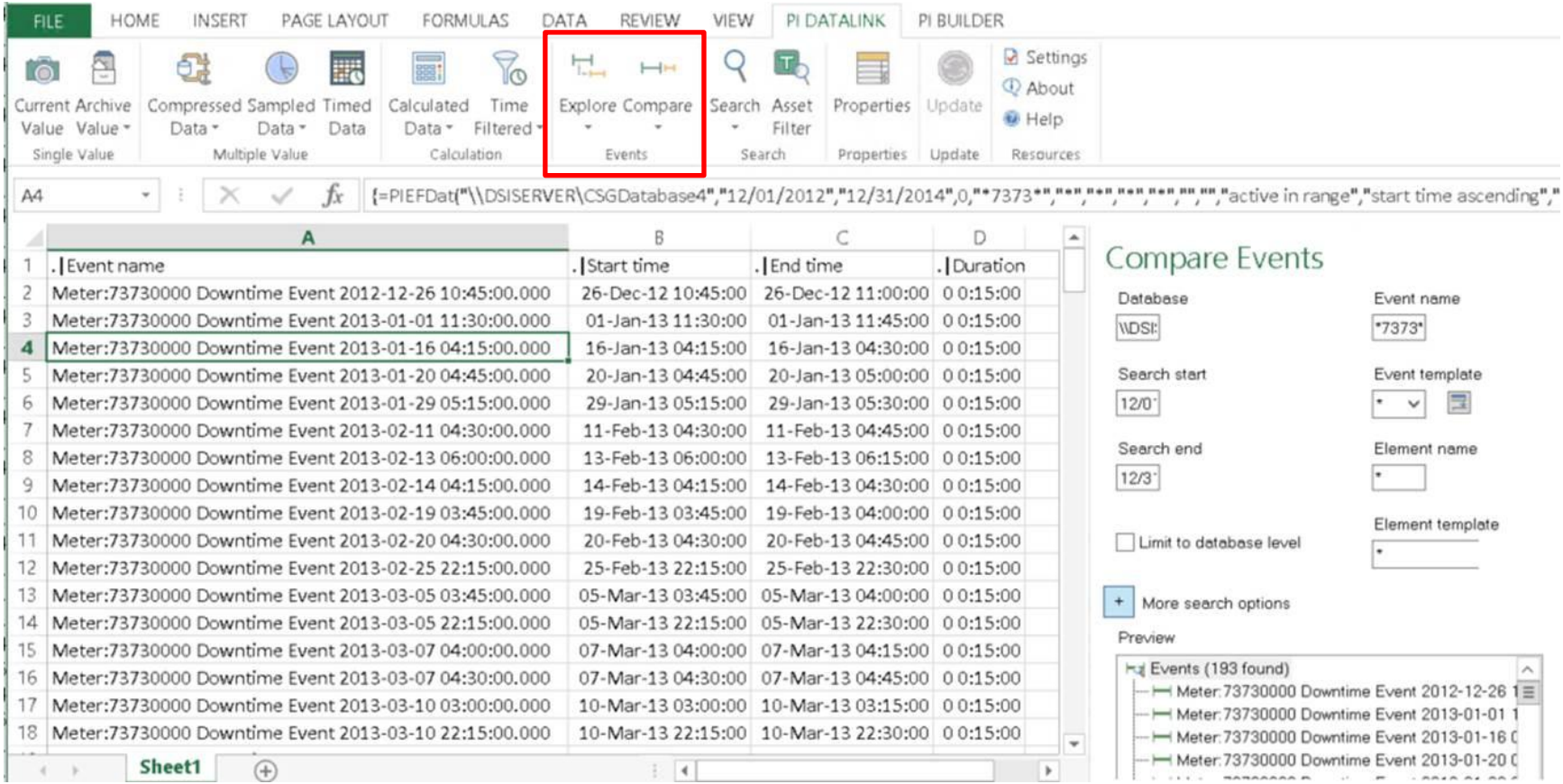


Event Frame Search 1

Filter

Name	Duration	Start Time	End Time
Meter:73730000 Downtime Event 2013-05-20 21:15:00.000	1:15:00	5/20/2013 9:15:00 PM	5/20/2013 10:30:00 PM
Meter:73730000 Downtime Event 2013-05-20 10:45:00.000	1:15:00	5/20/2013 10:45:00 ...	5/20/2013 12:00:00 PM
Meter:73730000 Downtime Event 2013-05-20 09:15:00.000	1:15:00	5/20/2013 9:15:00 AM	5/20/2013 10:30:00 AM
Meter:73730000 Downtime Event 2014-05-15 03:15:00.000	1:00:00	5/15/2014 3:15:00 AM	5/15/2014 4:15:00 AM
Meter:73730000 Downtime Event 2014-05-13 22:15:00.000	1:00:00	5/13/2014 10:15:00 ...	5/13/2014 11:15:00 PM
Meter:73730000 Downtime Event 2014-05-15 17:30:00.000	0:45:00	5/15/2014 5:30:00 PM	5/15/2014 6:15:00 PM
Meter:73730000 Downtime Event 2014-05-15 16:30:00.000	0:45:00	5/15/2014 4:30:00 PM	5/15/2014 5:15:00 PM
Meter:73730000 Downtime Event 2014-05-14 22:00:00.000	0:45:00	5/14/2014 10:00:00 ...	5/14/2014 10:45:00 PM
Meter:73730000 Downtime Event 2013-11-03 01:15:00.000	0:45:00	11/3/2013 1:15:00 AM	11/3/2013 1:00:00 AM
Meter:73730000 Downtime Event 2013-05-20 23:15:00.000	0:45:00	5/20/2013 11:15:00 ...	5/21/2013 12:00:00 AM
Meter:73730000 Downtime Event 2013-05-20 13:15:00.000	0:45:00	5/20/2013 1:15:00 PM	5/20/2013 2:00:00 PM
Meter:73730000 Downtime Event 2013-05-20 04:45:00.000	0:45:00	5/20/2013 4:45:00 AM	5/20/2013 5:30:00 AM
Meter:73730000 Downtime Event 2013-05-20 01:15:00.000	0:45:00	5/20/2013 1:15:00 AM	5/20/2013 2:00:00 AM
Meter:73730000 Downtime Event 2014-05-21 04:15:00.000	0:30:00	5/21/2014 4:15:00 AM	5/21/2014 4:45:00 AM
Meter:73730000 Downtime Event 2014-05-20 09:30:00.000	0:30:00	5/20/2014 9:30:00 AM	5/20/2014 10:00:00 AM
Meter:73730000 Downtime Event 2014-05-20 05:00:00.000	0:30:00	5/20/2014 5:00:00 AM	5/20/2014 5:30:00 AM

Visualize EF in Excel via PI DataLink

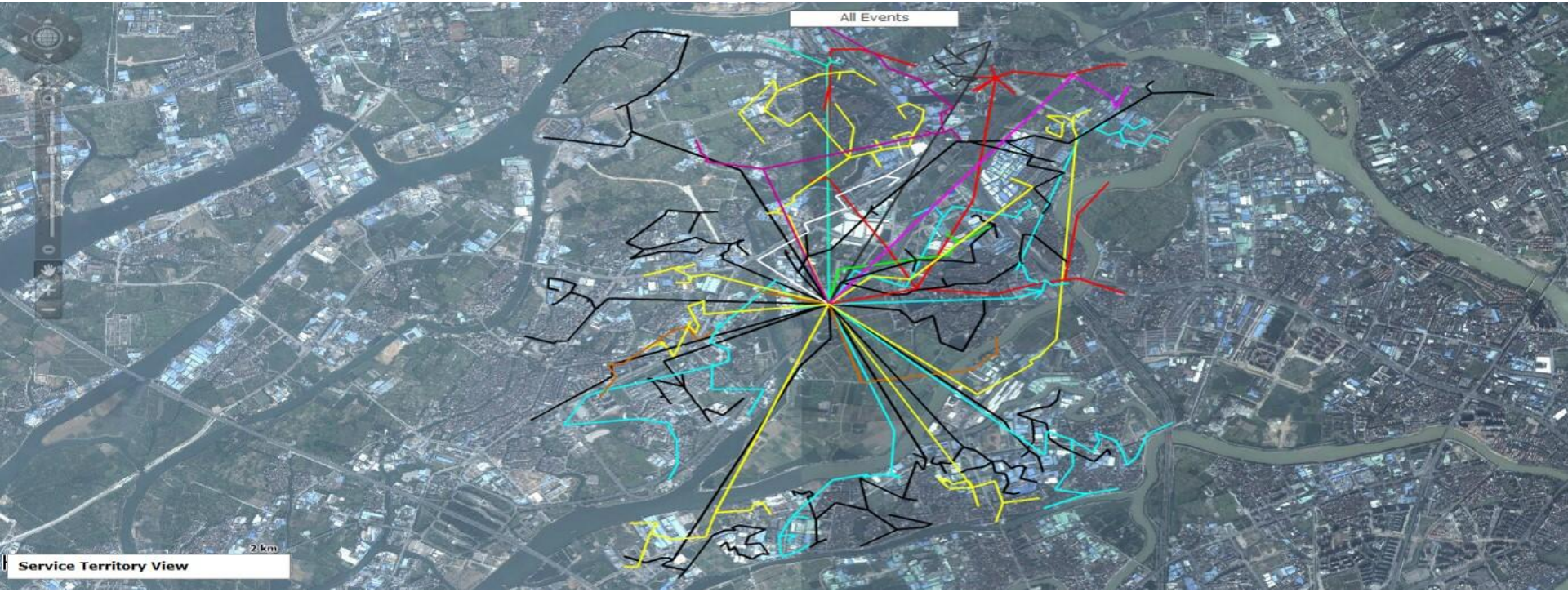


Reports to filter through hundreds of EFs

	A	B	C	D	E
1					
2	Start Time	12/1/2012	Event Name		
3	End Time	12/31/2013	Min Duration	45m	
4					
5	**Event name**	**Start time**	**End time**	**Duration**	
6	Meter:83197000 Downtime Event 2013-01-18 09:45:00.000	18-Jan-13 09:45:00	18-Jan-13 11:15:00	0 1:30:00	
7	Meter:83197000 Downtime Event 2013-03-07 10:00:00.000	07-Mar-13 10:00:00	07-Mar-13 18:15:00	0 8:15:00	
8	Meter:83197000 Downtime Event 2013-03-15 09:30:00.000	15-Mar-13 09:30:00	15-Mar-13 16:00:00	0 6:30:00	
9	Meter:31689001 Downtime Event 2013-05-15 09:00:00.000	15-May-13 09:00:00	15-May-13 12:15:00	0 3:15:00	
10	Meter:73730000 Downtime Event 2013-05-20 09:15:00.000	20-May-13 09:15:00	20-May-13 10:30:00	0 1:15:00	
11	Meter:73730000 Downtime Event 2013-05-20 10:45:00.000	20-May-13 10:45:00	20-May-13 12:00:00	0 1:15:00	
12	Meter:73730000 Downtime Event 2013-05-20 21:15:00.000	20-May-13 21:15:00	20-May-13 22:30:00	0 1:15:00	
13	Meter:83197000 Downtime Event 2013-08-20 09:00:00.000	20-Aug-13 09:00:00	20-Aug-13 11:15:00	0 2:15:00	
14	Meter:83197000 Downtime Event 2013-12-01 03:30:00.000	01-Dec-13 03:30:00	01-Dec-13 10:30:00	0 7:00:00	
15					

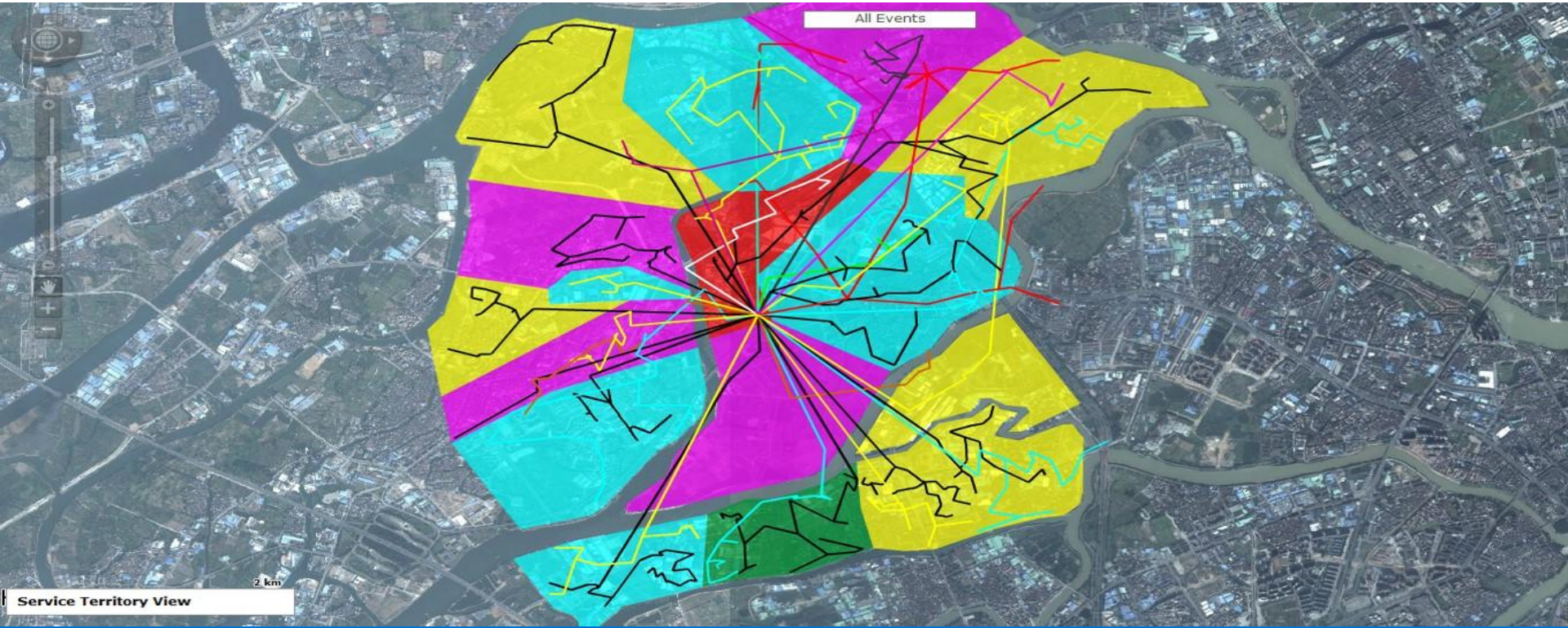
Use Case: Generic GIS Capability

Using CIM Model to Display Feeder Circuit in GIS



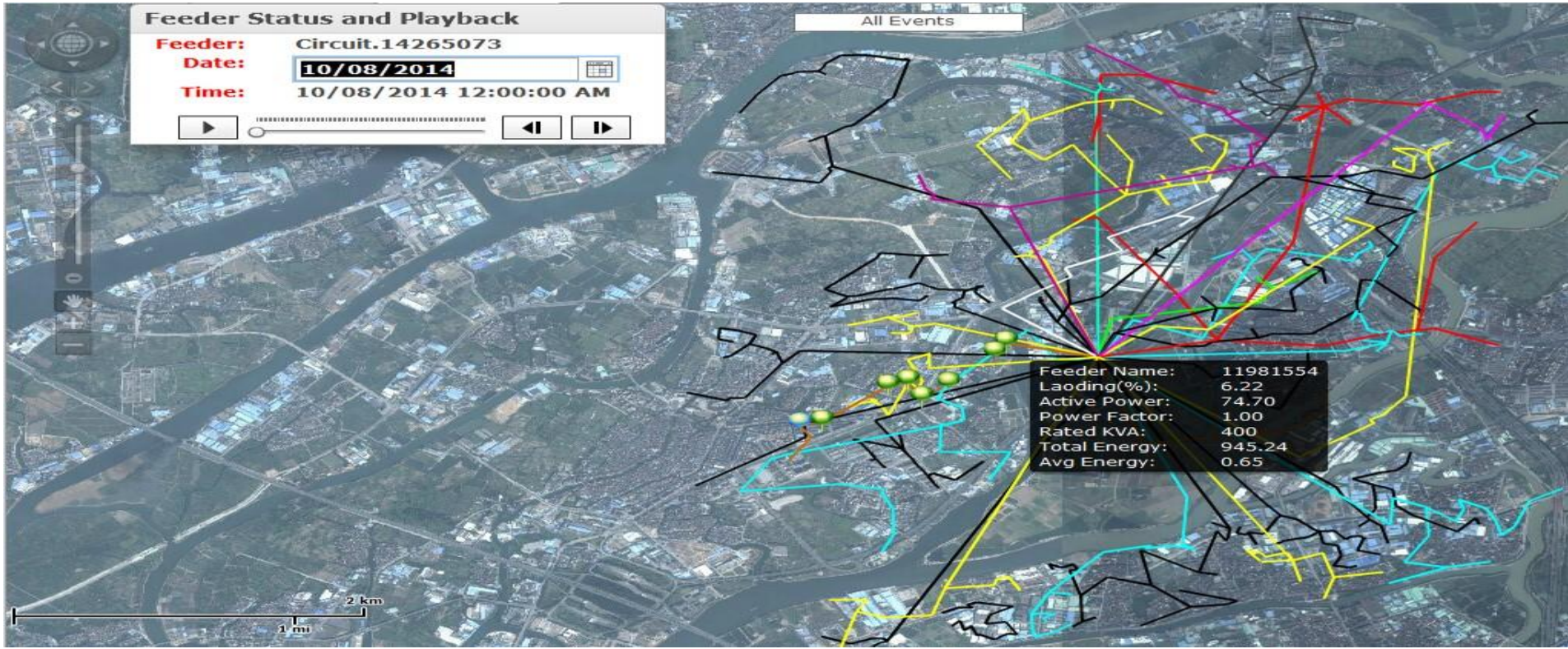
Use Case: Generic GIS Capability

CIM Circuit overlay with GIS Region



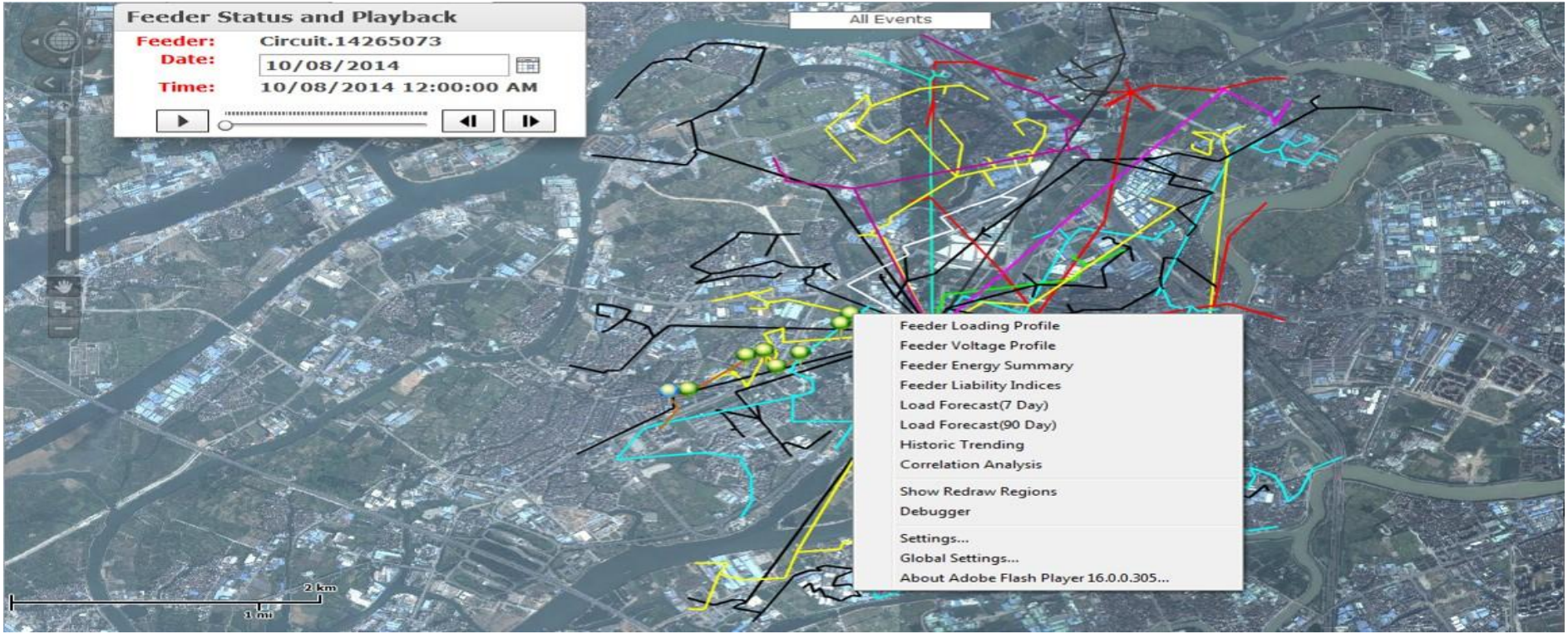
Use Case 1: Feeder Loading Analysis

Using GIS to dynamically show the feeder transformer loading and playback



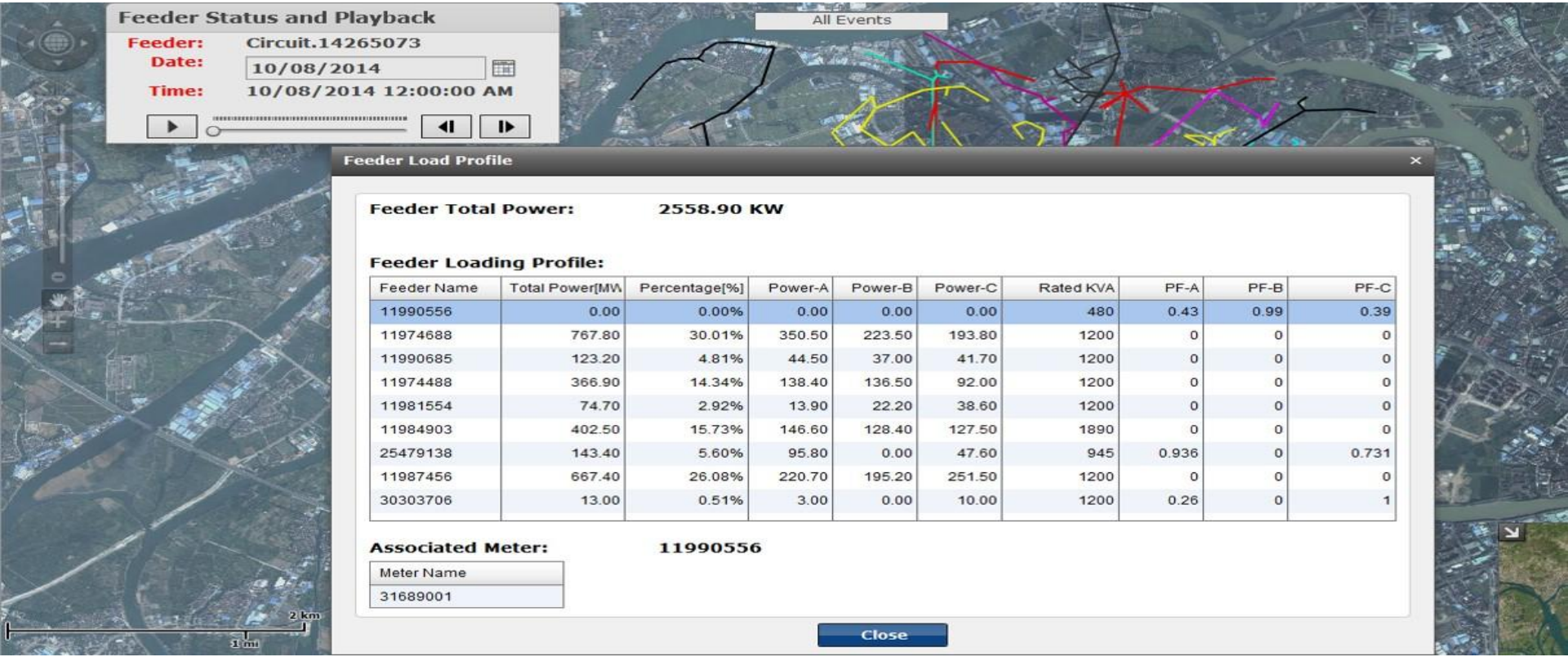
Use Case 1: Feeder Loading Analysis

Using Pull Down Menu to Access Other Functions



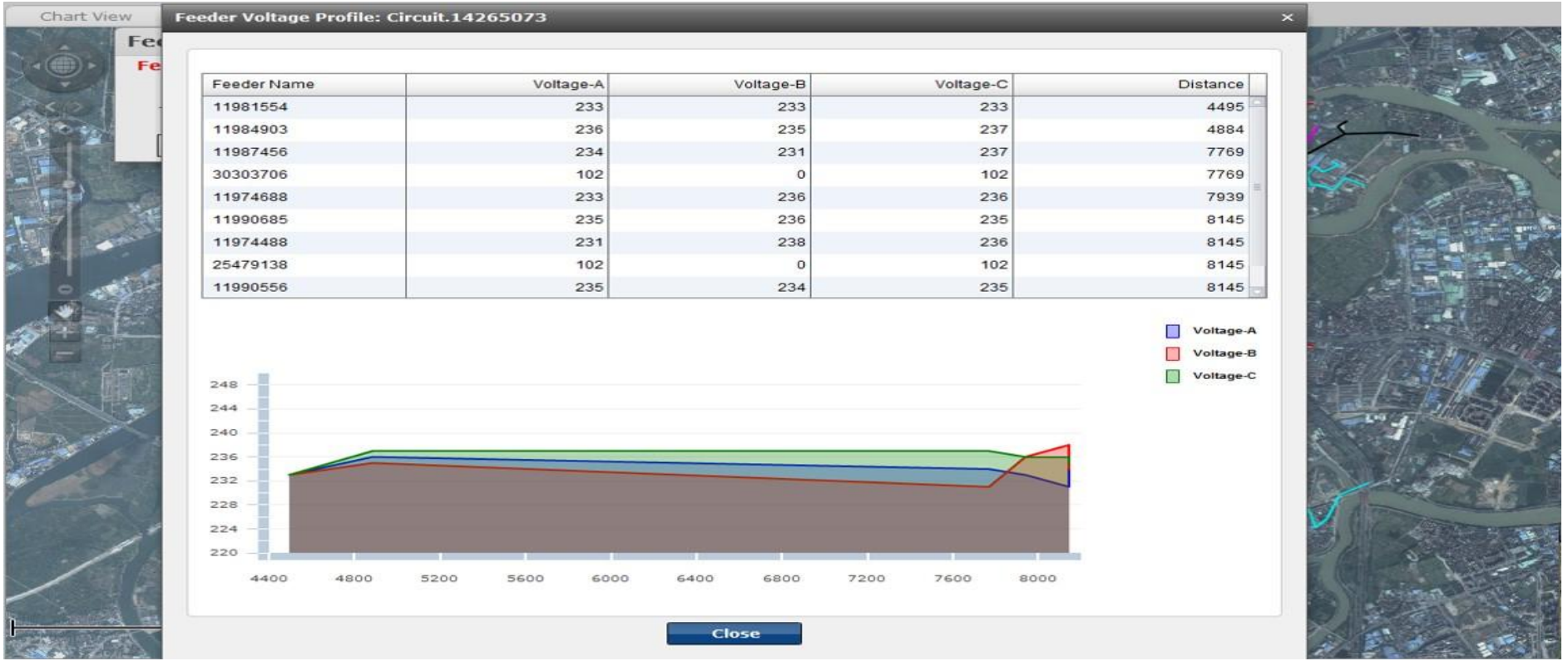
Use Case 1: Feeder Loading Analysis

Feeder Loading Profile and Distribution



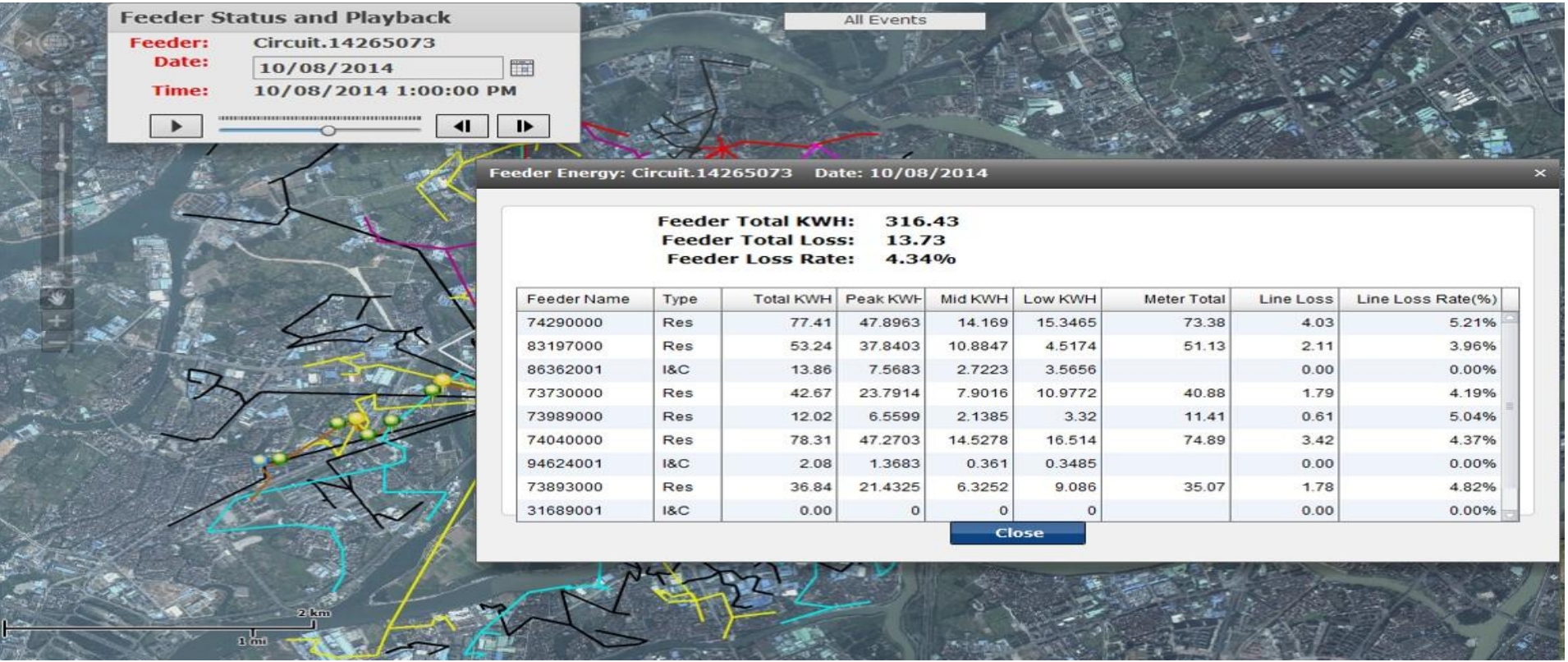
Use Case 1: Feeder Loading Analysis

Feeder Voltage Profile and Distribution



Use Case 2: Line Loss Analysis

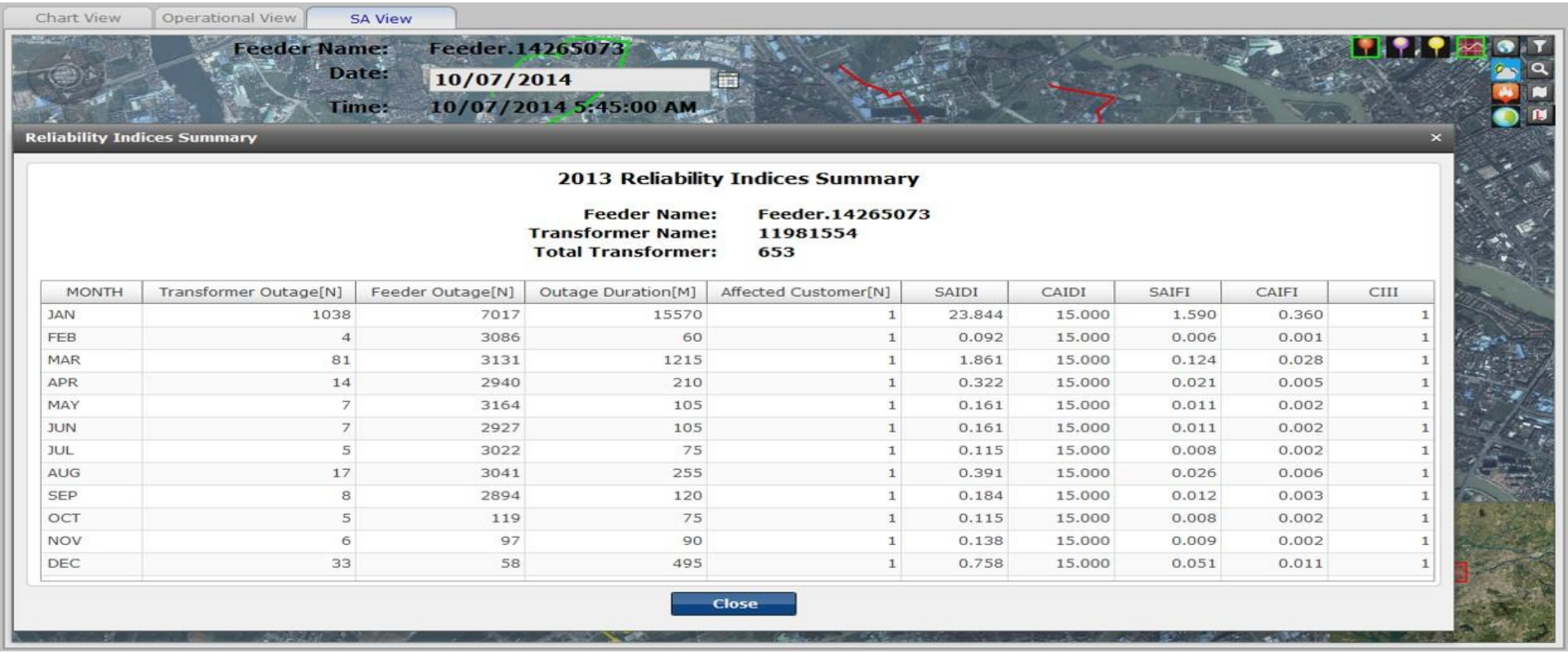
Feeder Total KWH and Line Loss Analysis



Feeder Name	Type	Total KWH	Peak KWH	Mid KWH	Low KWH	Meter Total	Line Loss	Line Loss Rate(%)
74290000	Res	77.41	47.8963	14.169	15.3465	73.38	4.03	5.21%
83197000	Res	53.24	37.8403	10.8847	4.5174	51.13	2.11	3.96%
86362001	I&C	13.86	7.5683	2.7223	3.5656		0.00	0.00%
73730000	Res	42.67	23.7914	7.9016	10.9772	40.88	1.79	4.19%
73989000	Res	12.02	6.5599	2.1385	3.32	11.41	0.61	5.04%
74040000	Res	78.31	47.2703	14.5278	16.514	74.89	3.42	4.37%
94624001	I&C	2.08	1.3683	0.361	0.3485		0.00	0.00%
73893000	Res	36.84	21.4325	6.3252	9.086	35.07	1.78	4.82%
31689001	I&C	0.00	0	0	0		0.00	0.00%

Use Case 3: Reliability Indices

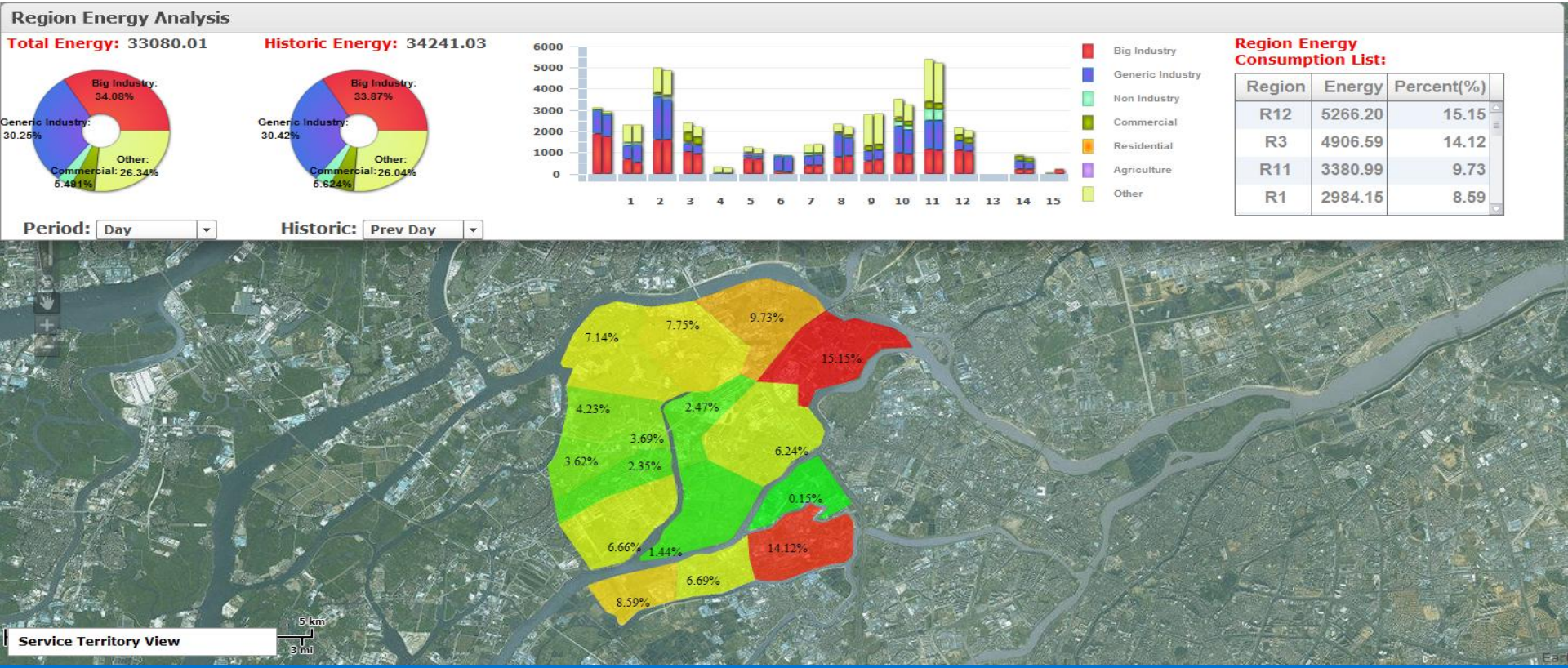
Feeder Reliability Indices Analysis



MONTH	Transformer Outage[N]	Feeder Outage[N]	Outage Duration[M]	Affected Customer[N]	SAIDI	CAIDI	SAIFI	CAIFI	CIII
JAN	1038	7017	15570	1	23.844	15.000	1.590	0.360	1
FEB	4	3086	60	1	0.092	15.000	0.006	0.001	1
MAR	81	3131	1215	1	1.861	15.000	0.124	0.028	1
APR	14	2940	210	1	0.322	15.000	0.021	0.005	1
MAY	7	3164	105	1	0.161	15.000	0.011	0.002	1
JUN	7	2927	105	1	0.161	15.000	0.011	0.002	1
JUL	5	3022	75	1	0.115	15.000	0.008	0.002	1
AUG	17	3041	255	1	0.391	15.000	0.026	0.006	1
SEP	8	2894	120	1	0.184	15.000	0.012	0.003	1
OCT	5	119	75	1	0.115	15.000	0.008	0.002	1
NOV	6	97	90	1	0.138	15.000	0.009	0.002	1
DEC	33	58	495	1	0.758	15.000	0.051	0.011	1

Use Case 4: Energy Efficiency

Energy Efficiency Analysis

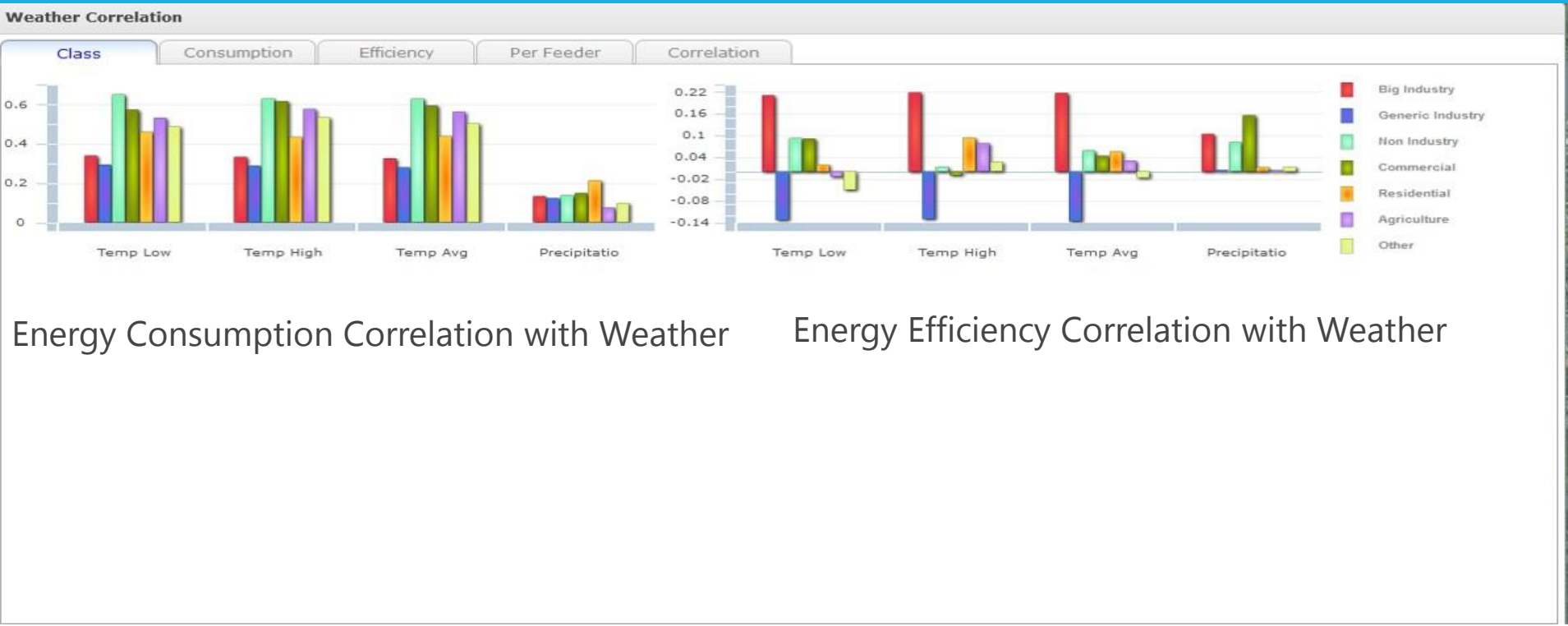


Use Case 4: Energy Efficiency

Energy Efficiency Heatmap

Use Case 4: Energy Efficiency

Weather Impact to Energy Usage Type

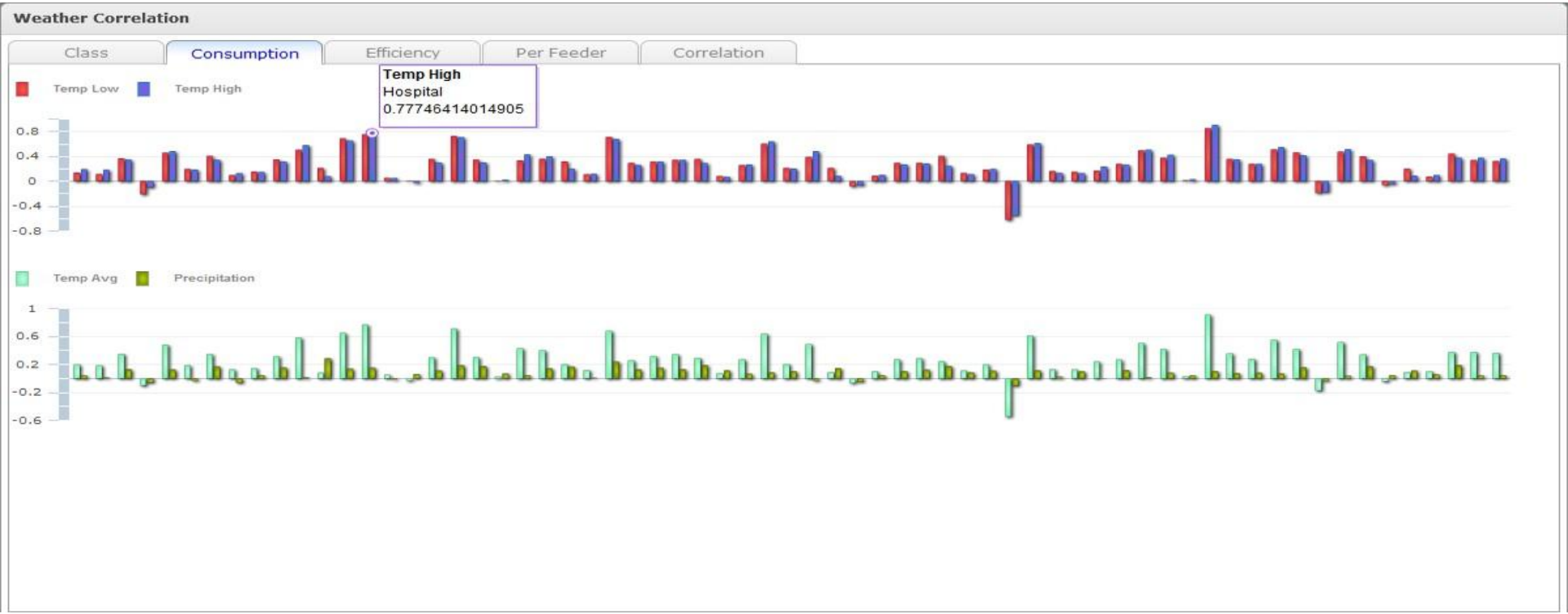


Energy Consumption Correlation with Weather

Energy Efficiency Correlation with Weather

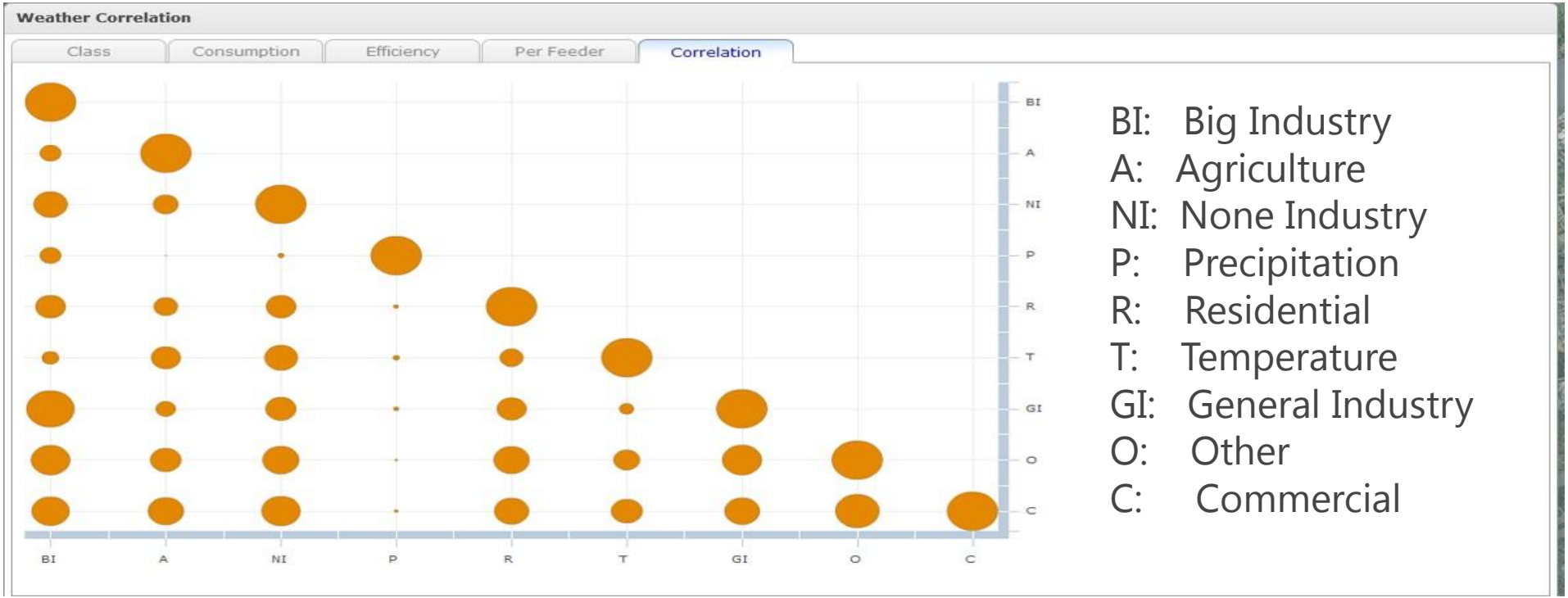
Use Case 4: Energy Efficiency

Weather Impact to Industry



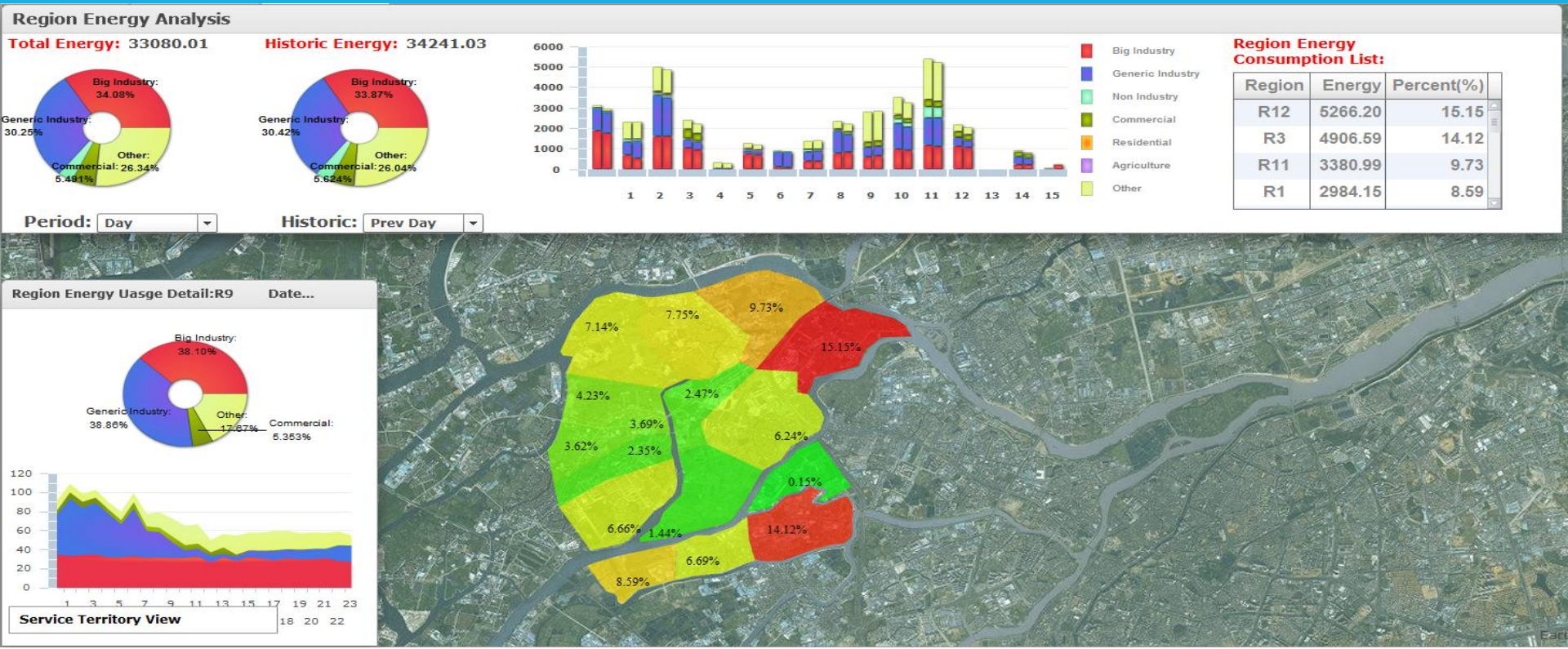
Use Case 4: Energy Efficiency

Industry Correlation



Use Case 4: Energy Efficiency

Region Energy Usage Detail



Microsoft

An E2E Operationalized pipeline for Predictive Analysis with PI Server 2015 and Microsoft AzureML, Power BI

Microsoft

Introduction: Azure ML

Azure Machine Learning

Hosted, fully-managed cloud service for operationalized machine learning and data science

ML Studio –

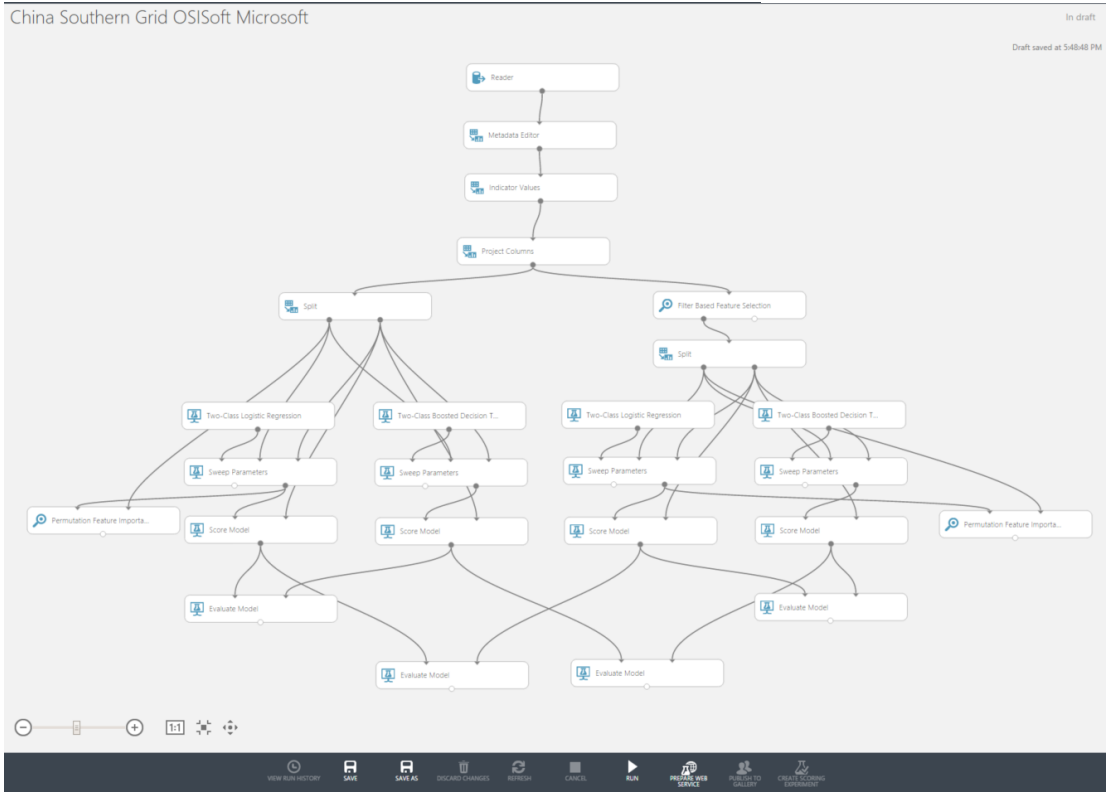
- Experiment and build ML based solutions
- Deploy solutions as web service APIs on the cloud

Services

- Request/Response and Batch web services of the solutions

Marketplace

- Monetize intelligent APIs on the cloud



Forecast Temperature and Energy Consumption

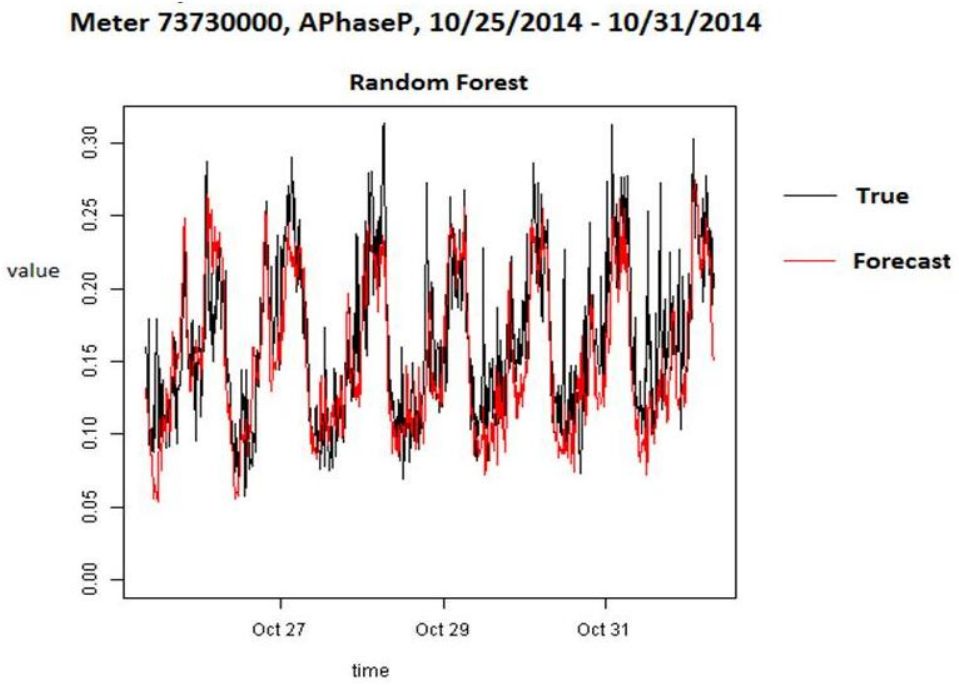
Microsoft

1. Collect data in Real-Time using the PI Server

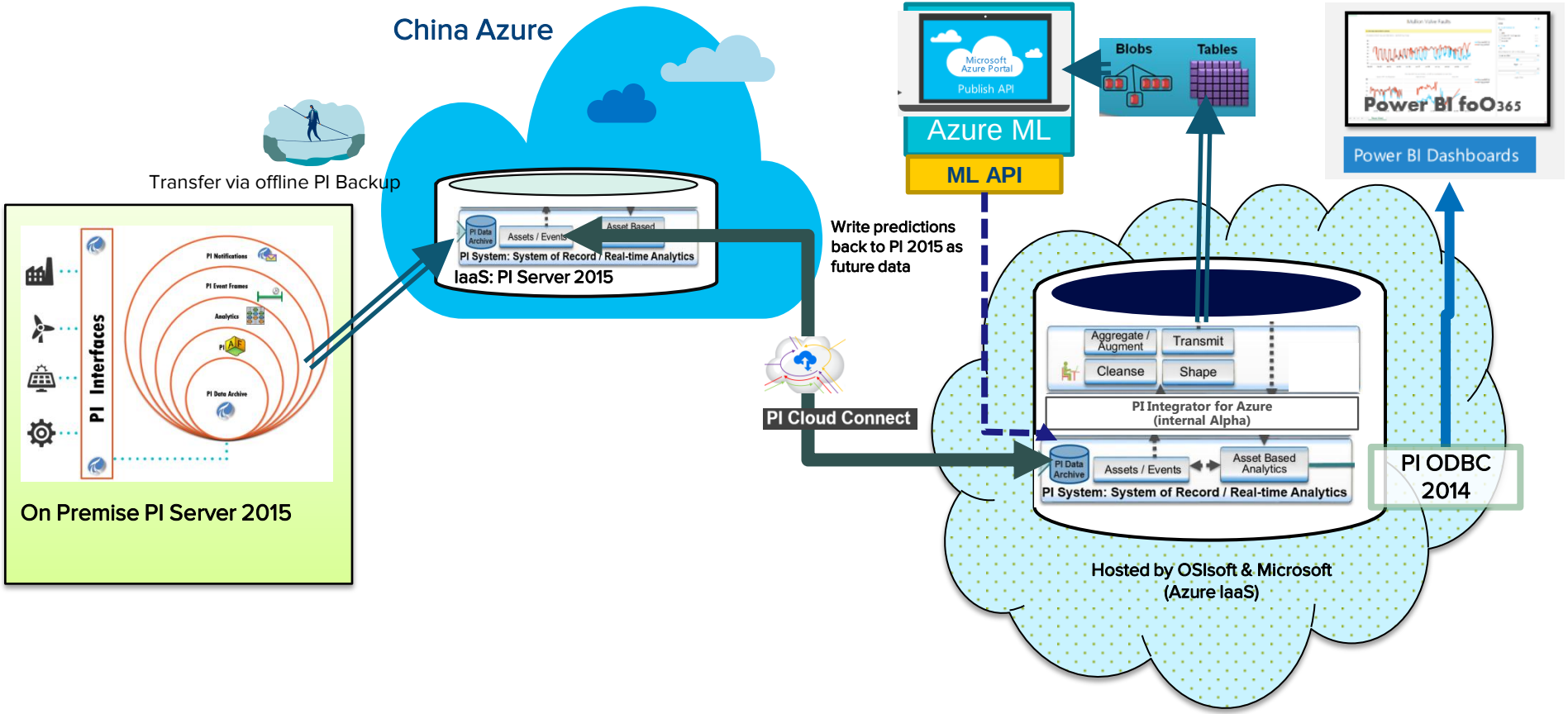
2. Train model for each meter to predict temperature and energy consumption at
   - different horizons – 7 and 90 days
   - 15 min. intervals

3. Detect potential energy savings
   * Over-Cooling/Heating
   * Space conditioned without occupancy

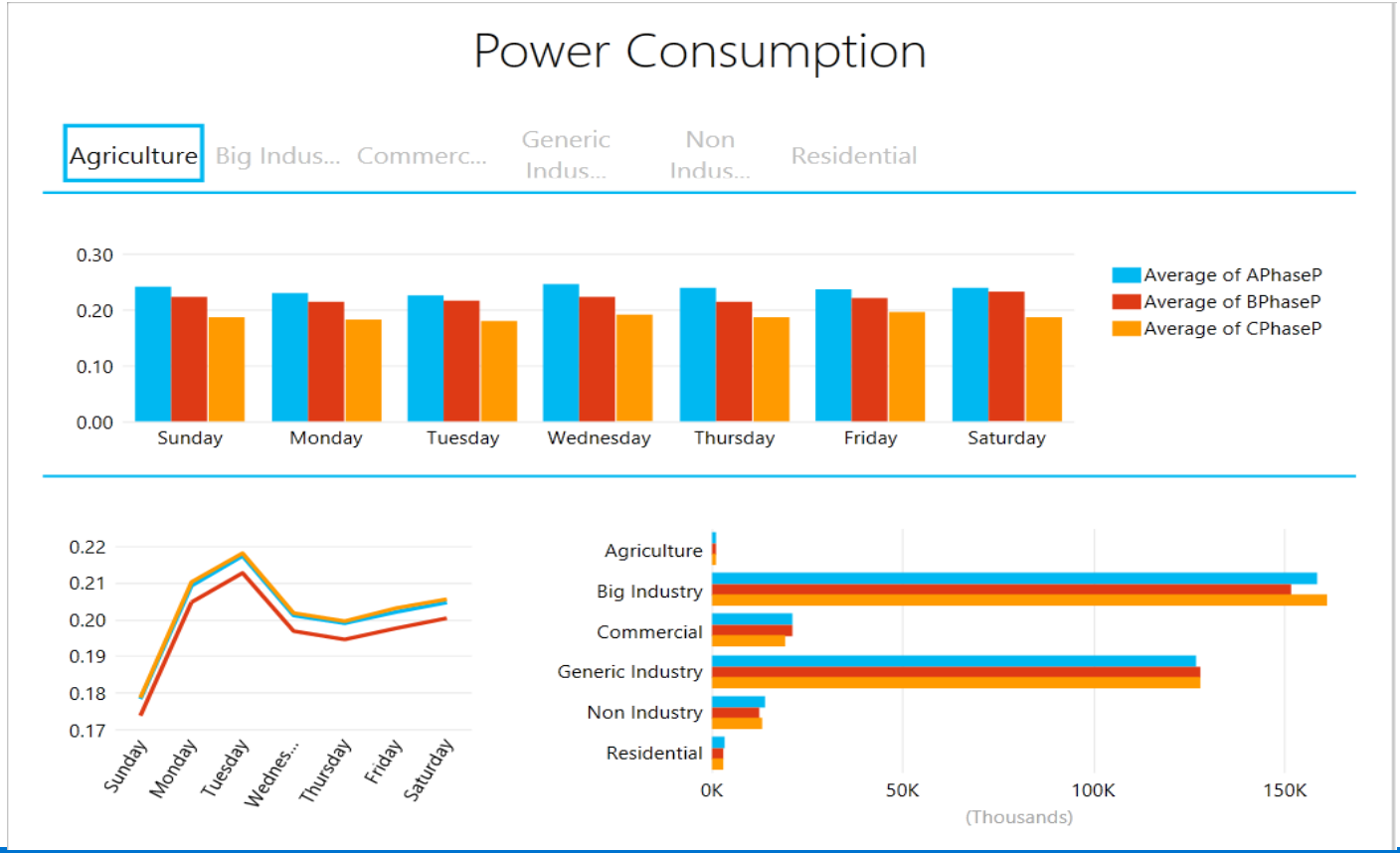
4. Corrective Actions :
   * Adjust Control Logic
   * Turn Off systems



Microsoft Azure Machine Learning Architecture

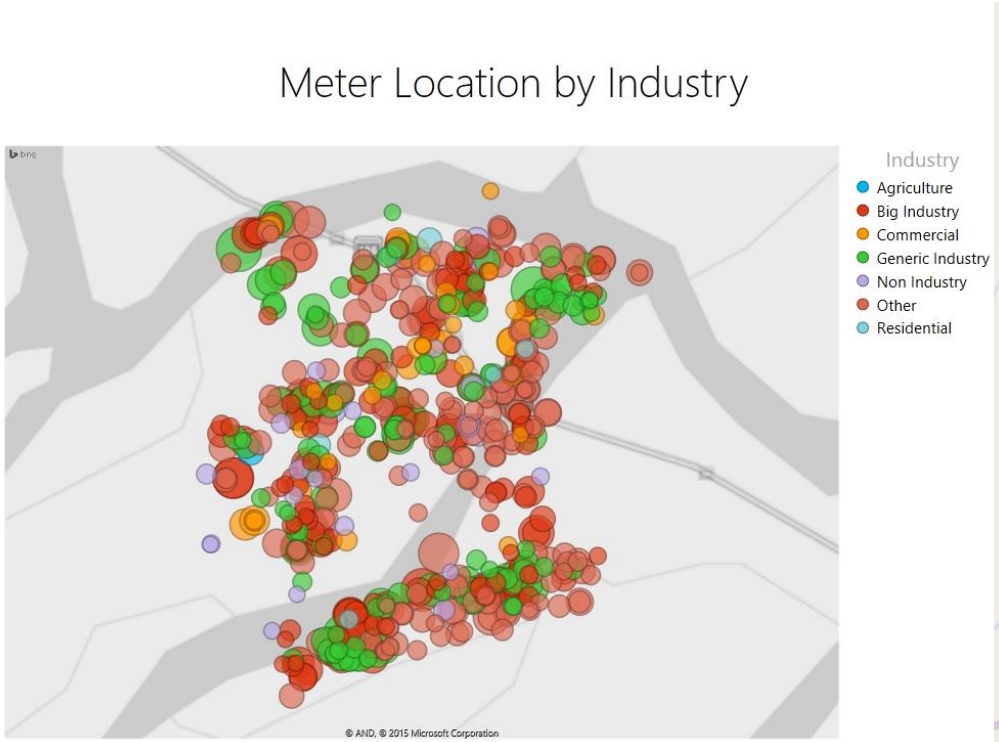


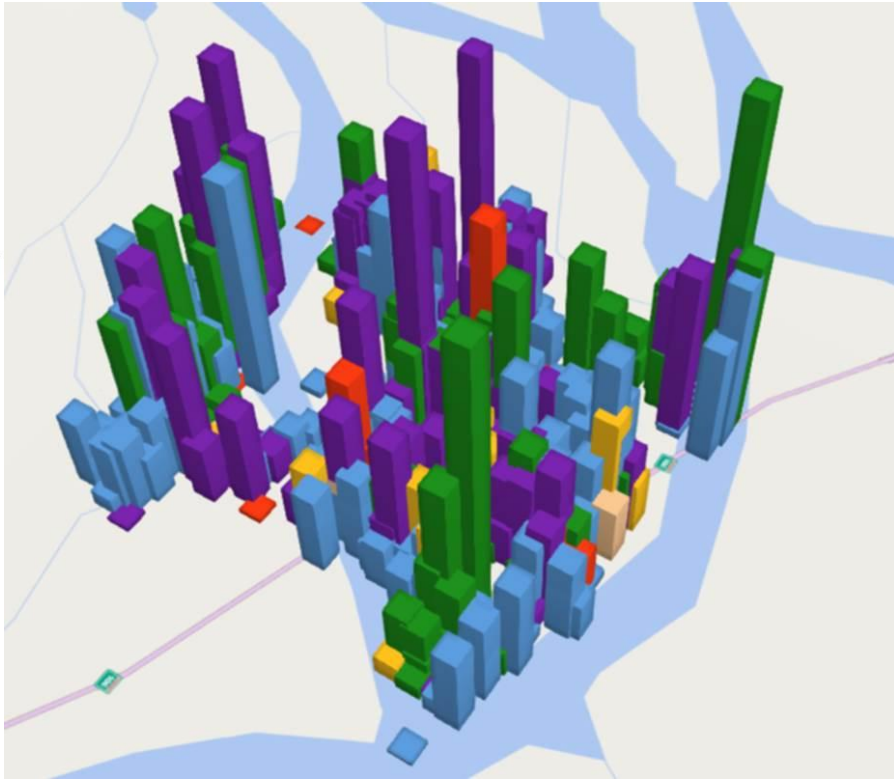
PowerBI Consumption Reports



PowerBI Consumption Reports

Microsoft



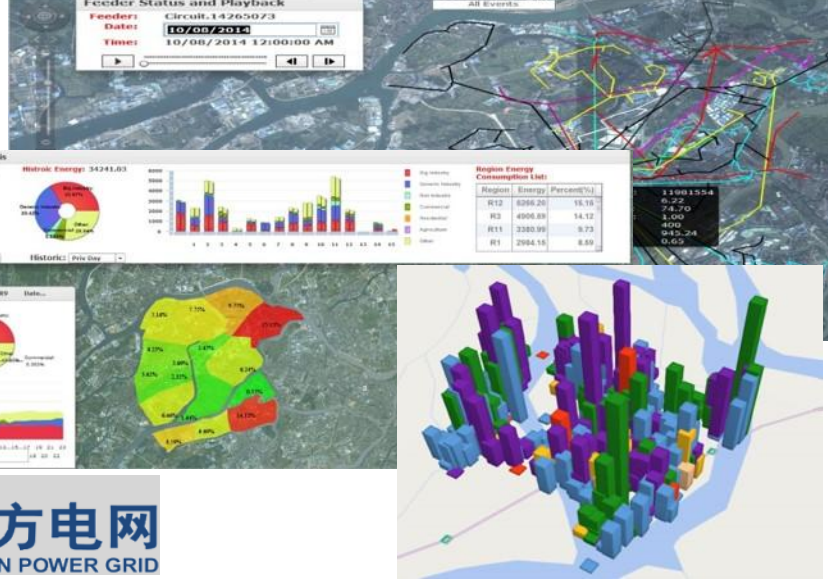


http://www.powerbi.com

E2E for Intelligent Grid

CSG EPRI is establishing an E2E big data technology in R&D, standards, and demonstration to approach our goal: an intelligent, efficient, reliable and green grid.

Dr. Li Peng, VP, CSG EPRI



中国南方电网 CHINA SOUTHERN POWER GRID

Business Challenges

A. A need for an End-to-End integrated "big data" infrastructure with unified models and standardizations

B. The same infrastructure to enable application development with visualization and analytics

C. Advanced technology such as predictive analytics technology can be utilized in the infrastructure

Solution(s)

A. PI System as the "big data" integration infrastructure

B. PI System to integrate data and power system topology model

C. PI System to integrate with GIS visualization and advanced predictive analytics technology

Results and Benefits

- One-stop shop for accessing and visualizing data for situational awareness
- End-to-End data integration to improve system reliability and customer service
- Enhanced prediction and forecasting for better planning and operations and more competitive to prepare for open market

Future Plan

- Enhancing visualization for big data analysis
- Adding non-structured data into CIM model
- Integrating PI System with Hadoop
- Expanding the architecture and implementation to 3 more cities

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Questions

Please wait for the microphone before asking your questions

State your
name & company

THANK YOU