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

Presented by
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China Southern Power Grid EPRI

Vijay K Narayanan
Microsoft
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.
The Southern Electric Power Research Institute (SEPRI), is a subsidiary of China Southern Power Grid, established on the basis of CSG Technology Research Centre on 6th August, 2010.

- The main business of SEPRI includes 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.
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

<table>
<thead>
<tr>
<th>Name</th>
<th>Outage Count</th>
</tr>
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<tbody>
<tr>
<td>Description</td>
<td></td>
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<tr>
<td>Categories</td>
<td></td>
</tr>
<tr>
<td>Analysis Type</td>
<td>Expression</td>
</tr>
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</table>

### Outage Count

**Daily Outage Totals**

```plaintext
DailyOutages: EventCount('Outage Count', 't', '')
LastDayMonth: if Day('**id') < Day('**') then 1 else NoOutput()
```

**Monthly Outage Totals**

```plaintext
MonthlyOutages: TagVal('Outage Count', '') - TagVal('Outage Count', 'mon(1)') + MonthlyTrigger * 0
```
Trend Outage Counters

Asset Analytics: Aggregated for Daily and Monthly Outages
Outage Calculation and Analysis
Event Frames (EF)

• Trigger Start Condition

<table>
<thead>
<tr>
<th>Name</th>
<th>Expression</th>
<th>Value</th>
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</thead>
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<tr>
<td>StartTrigger</td>
<td>TagVal('Outage Count','<em>') - TagVal('Outage Count',PrevEvent('Outage Count','</em>'))</td>
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• Event Attributes
  • Duration (Start and End Time)
  • Cause
  • Calculations related to Outage
EF for Meter Outages
**EF Showing Outage Duration**

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

<table>
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<tr>
<th>Event Frame Search 1</th>
<th>Event Frame Searches</th>
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**Filter**

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<tr>
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<td>5/20/2013 4:45:00 AM</td>
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Visualize EF in Excel via PI DataLink
Reports to filter through hundreds of EFs

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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

Feeder Status and Playback

Feeder: Circuit.14265073
Date: 10/08/2014
Time: 10/08/2014 12:00:00 AM

Feeder Name: 11981554
Loading(%): 6.72
Active Power: 74.70
Power Factor: 1.00
Rated KVA: 300
Total Energy: 945.24
Avg Energy: 0.65
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

Feeder Status and Playback

Feeder: Circuit.14265073
Date: 10/08/2014
Time: 10/08/2014 12:00:00 AM

Feeder Load Profile

Feeder Total Power: 2558.90 KW

Feeder Loading Profile:

<table>
<thead>
<tr>
<th>Feeder Name</th>
<th>Total Power[MW]</th>
<th>Percentage[%]</th>
<th>Power-A</th>
<th>Power-B</th>
<th>Power-C</th>
<th>Rated KVA</th>
<th>PF-A</th>
<th>PF-B</th>
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<td>11984903</td>
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<td>127.50</td>
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</table>

Associated Meter: 11990556

| Meter Name | 31689001 |

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Use Case 1: Feeder Loading Analysis

Feeder Voltage Profile and Distribution

<table>
<thead>
<tr>
<th>Feeder Name</th>
<th>Voltage-A</th>
<th>Voltage-B</th>
<th>Voltage-C</th>
<th>Distance</th>
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Use Case 2: Line Loss Analysis

Feeder Total KWH and Line Loss Analysis
## Use Case 3: Reliability Indices

### Feeder Reliability Indices Analysis

#### 2013 Reliability Indices Summary

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<tr>
<th></th>
<th></th>
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**Feeder Name:** Feeder.14265073  
**Transformer Name:** 11981554  
**Total Transformer:** 653
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

Weather Correlation

- Temp Low
- Temp High

Temp High
Hospital
0.77746414014905

Temp Avg
Precipitation
Use Case 4: Energy Efficiency

Industry Correlation

BI: Big Industry
A: Agriculture
NI: None Industry
P: Precipitation
R: Residential
T: Temperature
GI: General Industry
O: Other
C: Commercial
Use Case 4: Energy Efficiency

Region Energy Usage Detail

Region Energy Analysis
Total Energy: 33080.01
Historic Energy: 34241.03

Big Industry: 34.08%
General Industry: 30.27%
Commercial: 26.33%
Other: 8.21%

Region Energy Consumption List:

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<thead>
<tr>
<th>Region</th>
<th>Energy</th>
<th>Percent (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R12</td>
<td>5266.20</td>
<td>16.15</td>
</tr>
<tr>
<td>R3</td>
<td>4906.59</td>
<td>14.12</td>
</tr>
<tr>
<td>R11</td>
<td>3380.99</td>
<td>9.73</td>
</tr>
<tr>
<td>R1</td>
<td>2984.15</td>
<td>8.59</td>
</tr>
</tbody>
</table>

Region Energy Usage Detail R9

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

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

China Azure

Transfer via offline PI Backup

On Premise PI Server 2015

write predictions back to PI 2015 as future data

Hosted by OSIsoft & Microsoft (Azure IaaS)

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PowerBI Consumption Reports

Power Consumption

Agriculture  Big Indus...  Commerc...  Generic Indus...  Non Indus...  Residential

Monday  Tuesday  Wednesday  Thursday  Friday  Saturday

Average of APhaseP  Average of BPhaseP  Average of CPhaseP

Agriculture
Big Industry
Commercial
Generic Industry
Non Industry
Residential

0K  50K  100K  150K

(Thousands)
PowerBI Consumption Reports

Meter Location by Industry

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

**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