Unified Real-Time Network Topology Management Using Oracle Spatial
Xcel Energy
SmartGridCity
Overview

• Managing Dynamic Distribution Grid & IP Network
• Unified Electrical and IP Network Topology Management – Overview
• Oracle Spatial & CURRENT OpenGrid Solution
• Unified Network Building Blocks
Convergence of Electrical and Communication Networks

- Two distinct set of users with common goal requires both networks to be fully integrated
- Widespread deployment of smart sensor with actionable intelligence and communication requires robust Network Management System
Smart Grid Infrastructure

- Remotely configured and managed sensors
- Remotely configured and controlled electrical device

![Diagram of Smart Grid Infrastructure]

- Medium Voltage UG lines
- V&I Sensor
- CCE
- Fiber or other high speed link
- Distribution Substation
- Fiber, Wireless, BPL, GPRS, 3G, WiMax
- Device Controller
- Low Voltage lines
- Low Voltage Analytics /Sensor
- Meter
- Transmission Substation
- IEDs, SCADA data
Unified Networks

- **IP Network Management** –
  Centralized management of Network Elements (NE) and model network topology
  - Provisioning, activation, health check, data acquisition and control
  - Utilize spatial data for problem detection and Resolution
  - Acquire data from sensors and controllers associated with NE using IEC 61850, DNP3, IP and SNMP

- **Device Data Management** –
  Centralized management of sensor provided measurements and correlate data with related electrical device
  - Single repository with temporal element to maintain real-time and historic measurement data of electrical devices
  - Receive and processes events and alarm
Oracle Spatial NDM Enabled NE - Device Correlation

Feeder CLP-1

Fault on One-Phase of a Three-Phase Main Line

Feeder CLP-2

Sensor S1
Fault on One-Phase of a Three-Phase Main Line

Recloser Opens to Clear Fault

Oracle Spatial NDM Enabled NE - Device Correlation
Oracle Spatial NDM Enabled NE - Device Correlation

Feeder CLP-1

Recloser Opens to Clear Fault

Fault on One-Phase of a Three-Phase Main Line

Recloser opens To Isolate Fault

Feeder CLP-2

Sensor S1
Fault on One-Phase of a Three-Phase Main Line

Recloser Opens to Clear Fault

Recloser opens To Isolate Fault

Feeder CLP-2

OpenGrid Closes Tie Switch

Sensor S1
- Track and report Communication Network Element and sensor status using geographic and electrical feeder extent
- Maintain “As-built model” and “As-operated” network model
- Before fault, Sensor S1 reported voltage and current for Feeder CLP-1. After switching the same Sensor reports measurements for feeder CLP-2
Spatial Powered Smart Grid

Legacy GIS

• Requires dual architecture to store data
• Proprietary API and spatial queries
• Isolated system requires extensive integration effort and data translation
• Often supports only single network
• Lacks built-in temporal features to take actionable intelligence using historic data

Oracle Spatial – CURRENT
OpenGrid

• gIS – Unified data storage
• SQL based spatial query support
• Enterprise system enables ease of integration
• Build-in support for OGC and SQL
• Multiple Network Support to enable self-healing
• Unified network topology, real-time and historic data provide actionable intelligence to prevent faults
Data Model Differences

Corporate GIS – As Built
- Complex, numerous objects & attributes
- Emphasis on asset detail, not speed
- Many update users, each with unique view
- Includes proposed facilities
- Static devices show nominal status
- New Smart Grid devices are yet to be modeled

Smart Grid – As Operated
- Simplified, essential objects & attributes
- Emphasis on speed
- Many operations users share one view
- Focus is on existing facilities
- Dynamic devices show current status
- Integrated Network models enables association between Smart Grid devices and grid
Solution Approach

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• Provide Smart Grid data management solution
• Geographic model based on Oracle Spatial without any proprietary abstraction
• Network Data Model based on standard Oracle NDM and API
• Configurable device rules to model network connectivity
• Schematic and Geographic Viewer
  – Manages “as-operated” view of the distribution network
  – Node and Links populated using two-port modeling
  – Path and Path Link used to enable topology management
OpenGrid Data Sources

OpenGrid User Data

NDM Metadata

Nodes → Paths

Links → Path Links

Electric As-Built Network Model (GIS)

Substation Measurements (SCADA)

Meter Data (AMI)

Feeder Sensor Data

OpenGrid Oracle Spatial RDBMS

Device Engineering Properties

Real-Time Solution
• Red Hat Enterprise Linux
• Oracle RDBMS
• JEE application server – Oracle App Server to provide browser based thin clients and external system interfaces
• IDE – Eclipse
• Hibernate to model spatial data in a standardized way by abstraction
• CURRENT DNP3/IP OSI Layer 7
Architecture

- IEC 61968 CIM and OGC CIM inspired distribution data model
- Load–On–Demand Analysis to manage very large network analysis
  - Web client utilizes LOD Java API for network applications
  - Spatial workspace for long term transaction and incremental import from the legacy GIS
  - Periodic versioning of network data model to maintain network operations history
Oracle Spatial Enabled Analysis in OpenGrid

- Geo-coding – Identify street location of sensors and network element reporting communication loss
- Geometry Processing – Analyze distribution asset performance by electrical and geographical boundaries
- Network Analysis generated schematics/ one-line diagram
- Network Modeling
  - Discovering Reachability functions to transfer the load between substation
  - Tracing with direction and shortest path for the Fault Location Isolation & Restoration
  - Enable user define Search using various constraint
    - Cost, Depth, Distance, MBR
    - Constraints for Electric Network Contingency planning
GIS Integration Process

- **GIS Integration Methodology**
  - Proven and standards based GIS integration process supports multiple GIS data sources and formats
  - Supported Data Standards: XML, GML, IEC 61968–11 CIM, NRECA MultiSpeak
Infrastructure Data Management – using Oracle Spatial

OpenGrid Networking
For Utility Communications and Asset Management Engineers

- Network Manager
- Element Manager
- Device Data Manager

Intelligent Control
Data Acquisition
Metrology Database

“Smart Communication” Adaptors - Secure and Encrypted IP, SNMP, DNP3, IEC-101, IEC-104, IEC 61850, DSLM, PRIME

OpenGrid Distribution
For Utility Operations, Planning and Reliability Engineers

- System Optimization
- Distribution Management

Notification Services
Analytics Services
Topology Manager
Real-Time Power Flow

“Smart Integration” Adaptors - Middleware Neutral XML, OGC GML, IEC 61968, ICCP, OPC, MultiSpeak

Wireless Mesh Cellular DSL WiMax Fiber Cable BPL

UTILITY INFRASTRUCTURE COMPONENTS
- Cap Banks
- Transformers
- Meters
- RTUs
- Reclosers
- Sensors
- IEDs
- Tap Changers
- PHEV
- Switches

UTILITY ENTERPRISE SYSTEMS
- GIS
- Data Historian
- Work Management
- SCADA
- Billing/CIS
- OMS
- MDM
- Asset Management
- Power System Planning
- Corp Svc ERP/BI
Spatial Network User Interface

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• Electric Grid View
  – Provides access to real-time electric grid status
  – Historic data for analysis
  – Real-Time Distribution Power Flow Analysis to optimize the power delivery

• Network View
  – Provides access to communication network status and configuration
  – Root Cause Analysis of Network Elements
SmartGridCity™ – Boulder, CO

Smart Grid Deployed – The Xcel Energy Example

Installation of sensing equipments, two-way communication network for distribution grid automation and real-time AMI to provide:

- **Transformer Monitoring** - real-time decisions based on current grid conditions
- **Feeder Automation** - monitoring power flow, outages and asset device health to provide centralized Volt-VAR control and Dynamic Voltage Optimization
- **Smart Distribution System** – real-time data on power consumption, outages, restoration and fault locations

Utilizing

- **Advanced sensing** technology to monitor feeder condition
- Two-way, low latency **real-time communications**
- Unified Communication and Electrical grid topology management
System detected fault current and sent fault alarms indicated the location of the cable failure.
Spatial Feature Wish List

• Connectivity model import from proprietary GIS data models to Spatial Network Model
• Temporal support to track network model changes over the time
Summary

• Oracle Spatial is a core component of OpenGrid’s unified communication and electrical topology management to deploy the Smart Grid solution
• Unified networks enables self-healing and optimized distribution network operations Asset Management, Strategic Planning, Tactical deployment of sensors and visualization
• GML and CIM standards based GIS integration leads to
  – Removes limits imposed by proprietary data model
  – Improves GIS data accessibility
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