Wireless in Nuclear at Exelon

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Digital Plant Innovation
Exelon Overview

Exelon Generation

- Largest merchant fleet in the nation ~33 GW of capacity, with unparalleled upside
- One of the largest and best managed nuclear fleets in the world (~19 GW)
- Significant gas generation capacity (~10 GW)
- Renewable portfolio (~1 GW), mostly contracted

Exelon Utilities

- Largest electric and gas distribution company in the nation with ~10 M customers
- Diversified across multiple jurisdictions - Illinois, Maryland, Pennsylvania, Delaware, New Jersey, Wash DC
- Significant investments in Smart Grid technologies
- Transmission infrastructure improvement at utilities

Exelon Generation

Power Generation

- Exelion is the largest competitive integrated energy company in the U.S.

Exelon Utilities

BGE, ComEd, PECO, & PEPCO

Constellation

- Leading competitive energy provider in the U.S.
- Customer-facing business, with ~2.5 M customers and large wholesale business
- Top-notch portfolio and risk management capabilities
- Extensive suite of products including Load Response, RECs Distributed Solar

Competitive Business

Regulated Business
What are the Possibilities?

**Advanced computer applications**

- Implementation of pattern recognition software and physics/operating experience based “Analytics” to provide advance warning subtle but real failure modes
- “Analytics” identify the type of failure and recommend outages including work order generation, parts and scheduling of the asset outage
- “Analytics” monitor key performance indicators (cost, inventory, maintenance strategy, etc) to identify potential vulnerabilities as well as savings opportunities

**Organizational Performance**

- Technology allows for the centralization of data and more effective monitoring
- Improved computer applications/interfaces allow for improved productivity and performance of plant staff

**State of art communications infrastructure**

- Wireless infrastructure that provides cost effective method to utilize wireless sensors and innovative monitoring/predictive technologies
- Low cost wireless sensors (design once-install many) installed to improve predictive technology and facilitate elimination of high cost time based maintenance
The Internet of Things enables multiple devices to communicate through a common interface, which is typically a wireless connection to the cloud.

Many different types of devices can be connected to IoT (Phones, thermostats, appliances, vehicles, etc).

Ultimately, data is sent back and forth between the devices that comprise the IoT.

Sensors are used to collect data from devices.

Cloud
Predix Asset Performance Management (APM)

- Transform PRiSM APR models to Predix APM
- Co-developing advanced analytics models including
  - Fault diagnostic
  - Thermal Performance
  - Load following
  - Startup & shutdown monitoring
- Form Building software for data collection (PI Process, user created apps, etc.)
- Direct Web Hosted Applications for Desktop, and mobile applications
- Meridium APM – Maintenance Optimization

Unified Platform across all of Ex Gen

Core Products & Platform

Core Products

- **Asset Performance**
  - **RELIABILITY** Increase availability and longer asset life
- **Operational Optimization**
  - **RISK MITIGATION** Lower operations and financial risk
  - **COST REDUCTION** Lower operating costs with great efficiencies
- **Business Optimization**
  - **PROFITABLE GROWTH** Increase production for market advancement
- **Cyber Security**
  - **SECURE PLATFORM** Monitoring of connected industrial equipment
- **Advanced Controls**
  - **AUTOMATED SYSTEMS** Control System will be automated based on Analytics

Presently Available

Under Development

Custom Solution Platform

OPEN DEVELOPMENT
APM Reliability Management

Complete visibility to status, threats, activities, and outcome

Analytics  Alert  Analysis  Case  Action  Learning
Centralized Performance Monitoring

**LEGEND**
- IMPLEMENTED (Continue to develop)
- NOT IMPLEMENTED (Implementation in progress)
- IN DEVELOPMENT (Development in progress)

**Wireless Sensors**
**RadPro Sensors**
**DAS/ WiFi**
**Digital Worker (EWP)**
**Thermography/ Acoustic Continuous Monitoring Sensors**

**AMS Bridge Predictive Data**
**Computers Data Historian (Edge Devices)**
**Pattern Recognition**
**Work Order Data**

**GE PREDIX (APM/Watchtower)**
(Integration of Data sources, Advanced, Analytics, Machine Language, etc.)

**Centralized Monitoring**
**Stakeholders (Engineering, Work Management, Maintenance, etc.)**
Value of Additional Sensors – Condensate Booster Pump Example

**What we have in M&D APR Model Today:**
- Pump Status – turn model on/off
- Thrust Bearing Temperature
- Motor Lo Sleeve Bearing Temperature

**What we don’t have:**
- Individual Pump Suction Pressure (Local Gauge Instrument)
- Individual Pump Discharge Pressure (Local Gauge Instrument)
- Suction Flow (Not available – HDR FLOW ONLY)
- Discharge Flow (Not available – HDR FLOW ONLY)
- Header Discharge Pressure (in PI – cannot be correlated at the component level)
- Header Flow (in PI - cannot be correlated at the component level)
- No motor current or voltage
- No vibration data (taken monthly manually)
- No oil information in PI

**Motor/Pump Failure Modes**
- High Bearing Temperature
- High Motor Winding Temp
- Worn Thrust Bearing
- Motor Bearing Lubrication
- Worn Motor ODE Bearing
- Worn Pump DE Bearing
- Worn Pump Internals
- Shaft Misalignment
- Shaft Imbalance
- Power Supply Harmonics
- Power Cable Damage
- Rotor Bars Broken
- Stator Winding Fault
- Rotor Eccentricity
- Loose Foundation
- Pump Cavitation
- Supply Line Power Problem

**Limited Focus Today**

**No Sensor Coverage**

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Truth in Numbers – Think Applications

Current State
- Wireless radios
- Mobile Workers (electronic work packages)
- Temperature sensors
- Vibration sensors (limited)

Future State
- Current State plus:
  - More vibration sensors
  - Dosimetry
  - Gauge readers
  - Valve position sensors
  - RFID tags
  - Structural Health Monitoring

We could add over 1,000 sensors per unit
Why the Focus on Wireless?

Majority of Cost for Wireless

Wired sensor cost adds up quick....

Hardware

Install

Design Mod

All In Cost
An Attractive Alternative

Distributed Antenna Systems (DAS)

Control network volume and performance

Bring signal into areas that have poor coverage.
**How it Works**

**Option A:**
- **Antenna**
- **SOLiD Base Station Interface (RF Filtered, attenuated, and controlled)**
- **SOLiD Optical Distribution Unit (Converts RF to light for distribution through fiber)**

**Option B:**
- **RCF78 Leaky Coax Cable**
- **SOLiD 5W Remote**
- **Distributes signal to independent RF amplifiers then combines to one output port**

**Carrier Connection (Various RF’s)**
Ideal Configuration for Power Plants (example)

MRDU #1
MRDU #2
MRDU #3
MRDU #4
MRDU #5
MRDU #6

433MHz – Sensors and radio communications

700 LTE – tablets/cellular devices for mWM

450MHz – radio communications

900MHz – Sensors

Open
Open
DAS Wireless Sensor Network Setup – Typical

- **617' Elevation w/two antenna's**
- **579' Elevation w/two radiating cables**

**DAS 5W Remote**

**Fiber**

**DAS Head End (Base Station Interface and Optical Distribution Unit)**

**Power infrastructure**

**Predix Edge**

**Level 2 Data Historian**

- **Ethernet Connection**
- **Modbus**
- **OSIsoft**

Coax cable
Wi-Fi verse DAS – Which Approach is Better?

Option A
- RF spectrum
- Wi-Fi
- Corporate Network
  - Data Storage
  - Internet
  - Video
  - Tablets
  - Dosimetry
  - VoIP Phones
  - eWP
  - ePE

Option B
- RF spectrum
- 433MHz
  - Valve Position Monitoring
  - Gauge Readers
  - RFIDTags
- 915 MHz
  - Vibration
  - Dosimetry
  - 4-20 sensors
- 700-850 MHz
  - Tablets
  - Smart Phones
  - Ultrasonic (UT)
  - IR Cameras

Answer – we need them both
IIoT Requirements... *Voice, Video, Data and Sensor (VVDS)*
Why many different wireless technologies?

- Solution → Filling up the Technology gap
Frequency-hopping spread spectrum (FHSS)
Available Frequencies

450 MHz  900 MHz  1.4 GHz  2.4 GHz

Travels Further

Bounces easier

Larger Fresnel Radius

\[ r_{(\text{in mts})} = 17.32 \times \sqrt{\frac{d}{4f}} \quad (\text{in km}) \]

\[ r_{(\text{in ft})} = 72.05 \times \sqrt{\frac{d}{4f}} \quad (\text{in GHz}) \]
DAS – LTE on MPN

Wi-Fi Access Point
MPN Gateway - LTE

DAS Remote
Fiber

DAS Head End
Fiber

Cell Provider

Predix Cloud

LTE Cellular Data
Wireless Sensors – Petasense

• Petasense, Inc. manufactures and sells self-contained battery powered wireless devices to monitor rotational machinery.

• Using various on-board sensors, the devices collect raw data, process, and feed it to cloud services for examination.

• The processed data is then examined with machine learning for patterns and anomalies to help determine future failures and equipment wear and tear.
Cypress Gauge readers (900 MHz) project

- Leaky Wire/Distributed Antenna System (DAS) 900 MHz Network
- Wireless Gauge, Pressure & Temperatures Sensors and other innovative monitoring technologies – good for one way communication
- Site & Centralized monitoring
  - GE Predix Dashboard
  - GE Predix – APM/Analytics Implementation (2017 to 2018)
Innovative Technologies

Non-Contact Vibration (IRIS M)

• Measurement taken without contact (Video camera)
• Displacement and motion of every pixel in the image are measured
• Custom image processing software generates vibragrams or waveforms.
• Software measures subtle motion and amplifies to be visible by the naked eye

On-Line Thermography

• Enables Thermography 24/7
• Remote Fault detection and Alarm Generation
• Remotely Monitor Multiple Critical Substation Assets from One Central Controller
• Automated Monitoring Tours and Full Manual Directed Control
New Sensor Technology for Advancing OLM

Online Transformer Monitoring Using IR Cameras, EMSA, DGA and Core & Winding Temperature

On-line Oil Particle Counter

Wireless Gauge Reader
Cycle Isolation Sensors

**Petasense**
- Sensors are Wi-Fi
- Purchased 10 sensors for POC

**Cutis Wright**:
- 900 MHz sensor will work on the DAS at NMP
vbOnline Pro

2300 System 1*

LoRa Gateway

DAS

Ranger Pro

vbOnline Pro

2300

Characterized Mechanical Condition Information

Analytics

Predix APM

Local CMO Tools

System Manager Tools

Operational Process Parameters

High Level Periodic Characterized Data

1. Daily/Shiftly, Automatic Characterized Data
2. Collected as Needed Diagnostic Data
3. Frequent, Automatic Diagnostic Data
Questions?