Asset Optimization and Condition-Based Maintenance (CBM)

Improving Reliability and Quality

Ann Moore – Business Development Executive
Agenda

• Asset Management Issues and Trends
• Utility Use Cases
  – PSE&G CMMS
  – SDG&E RtCBM
• Benefits and ROI
• Summary and Q&A
Asset Management

1. Traditional asset management approaches
   - Issues
   - Limitations

2. Evolution of maintenance practices
   - Past
   - Present
   - Future
   - Interval based
     - Time based
     - Counter based
   - Condition based
   - Real-time Condition based
   - Future Asset Management Practice
PSE&G

(Public Service Electric & Gas)

CMMS

(Computerized Maintenance Management System)
WHY? Asset Management - Inside Plant

What do you do when...

- You have $1.5B of installed plant with a replacement value of $5.4B
- Average age of the assets exceeds 40 years
- All equipment is expected to be used and useful all the time, and
- Maintenance expenditures erode earnings and capital replacement provides for no new revenue?
Equipment Age Profile in Utility

Transformers
Total - 955 units

Average Age- **37.4 Years**

Breakers
Total - 4578

Average Age- **40.6 Years**
The Mission

To optimize the investment in assets while *Improving* the overall system *reliability* of Electric Delivery
The Vision

To perform the right maintenance at the right time, based on the consistent analysis of data to ensure a safe, reliable, cost effective approach.
Functional Areas of CMMS

- **Data Collection and Consolidation**
  - Diagnostic and Inspection Data
  - Time-series Data
  - Relational Data
- **Asset Analysis and Reporting**
  - Condition Assessment
  - Criticality Assessment
  - Work Priorization
- **Maintenance Management**
  - Measurement Points
  - Work Order Generations
  - Maintenance Planning
Integrated for Success

System Integration
Service Assurance (Outage Management)
Work Management (Crew Management)
Wireless Communications
Graphic Information (AM/FM)
Decision Support (Data driven decisions)

People

+ Process

+ Platform

OSIsoft

VALUE NOW, VALUE OVER TIME
Implementation Overview

**PI Manual Data Logger**

**Workstations**
- RtPortal Thick (Smart) Clients
- RtPortal Web-based Clients

**OSIsoft Technology**
- PI - Time Series Database
- Analytical Tools
- Contextual Database
- RtPortal Web-Server

**Standard Interfaces**
- PI to PI - OLEDB - OPC - COM connectors - Batch

**ERP / MMS**
- Measurement Points
- Asset Definitions
- Mntc Plans
- Tasks
- Order History
- Mntc Orders

**Substation Gateway Server**

**DeltaX**
- Hydran
- Doble
- Distr SCADA
- MV 90
- Transm SCADA

**VALUE NOW, VALUE OVER TIME**
Data Correlation

Condition Assessment = \( f_1(m_1) + f_2(m_2) + f_3(m_3) \ldots + f_n(m_n) \)
Data Correlation (cont’d)

Operational Data
Data Correlation (cont’d)

Characteristic Data

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Algorithms
## Score Generator

### Equipment Condition Assessment Module

#### Peer Group
- **BKR TEST**

#### Algorithm
- **GCB 28-69KV - ACTION**

#### Scores for Individual Factors

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**Ready** 8/30/2005 9:44 AM
# Work Prioritization

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R |
| 2 | 0001 | 001 | 158 | 305 | PA | RE | OPEN | E-RECL | IPE-PA-RECL-ZSHOP | Pal. Recloser Control Inspection | 424 | B | 50000.00 |
| 3 | 0001 | 003 | 075 | 846 | CE | ME | OPEN | E-BAT | IPE-CE-SEG - COM-MEC | Gen. Battery (Transm.Dest.) | 118 | D | 25000.00 |
| 4 | 0001 | 003 | 055 | 56 | PA | ME | OPEN | E-BAT | IPE-PA-MAL - COM-MEC | Gen. Battery (Dist.Dept.) | 63 | B | 15000.00 |
| 5 | 0001 | 003 | 054 | 87 | PA | ME | OPEN | E-BAT | IPE-PA-SVAK - COM-MEC | Gen. Battery (Transm.Dest.) | -22 | B | 5000.00 |
| 6 | 0001 | 003 | 003 | 83 | PA | ME | OPEN | E-BAT | IPE-PA-SER - M1 | Pal. Battery (Transm.Dest.) | -162 | D | 5000.00 |
| 7 | 0001 | 003 | 073 | 66 | PA | ME | OPEN | E-BAT | IPE-PA-SER - COM-MEC | Pal. Battery (Transm.Dest.) | -122 | D | 5000.00 |
| 8 | 0001 | 002 | 468 | 21 | ME | ME | OPEN | E-LOTCH | IPE-ME-SMV - COM-MEC | Mot. Battery Charger (Transm.Dept.) | 118 | B | 2500.00 |
| 9 | 0001 | 002 | 466 | 22 | ME | ME | OPEN | E-LOTCH | IPE-ME-SMV - COM-MEC | Mot. Battery Charger (Dist.Dept.) | 118 | B | 2500.00 |
| 10 | 0001 | 002 | 462 | 22 | ME | ME | OPEN | E-LOTCH | IPE-PA-MAL - COM-MEC | Pal. Battery Charger (Dist.Dept.) | 130 | B | 2500.00 |
| 11 | 0001 | 001 | 888 | 86 | SO | ME | OPEN | E-BAT | IPE-SO-SNF - 41X | So OCB BKR 500 KV (12yr) | 600.00 | 2.5 | 8.7 | 784 | 167.50 |
| 12 | 0001 | 001 | 561 | 97 | SO | ME | OPEN | E-BAT | IPE-SO-SNF - 2PM | So OCB BKR 132 KV (Transm. Dept.) | 136.00 | 2.9 | 4.5 | 405 | 55.00 |
| 13 | 0001 | 001 | 561 | 197 | SO | ME | OPEN | E-BAT | IPE-SO-SNF - 41H | So OCB BKR 500 KV (Transm. Dept.) | 136.00 | 2.9 | 4.5 | 405 | 55.00 |
| 14 | 0001 | 001 | 561 | 00 | ME | ME | OPEN | E-BAT | IPE-ME-SVAK - COM-MEC | Mot. Battery Charger (Transm.Dept.) | 94 | A | 15000.00 |
| 15 | 0001 | 001 | 561 | 30 | ME | ME | OPEN | E-BAT | IPE-ME-SVAK - COM-MEC | Mot. Battery Charger (Dist.Dept.) | 94 | A | 15000.00 |
| 16 | 0001 | 002 | 553 | 75 | SO | ME | OPEN | E-BAT | IPE-SO-SNF - 2PM | So OCB BKR 500 KV (Transm. Dept.) | 53 | A | 15000.00 |
| 17 | 0001 | 002 | 553 | 75 | SO | ME | OPEN | E-BAT | IPE-SO-SNF - 41H | So OCB BKR 500 KV (Transm. Dept.) | 53 | A | 15000.00 |
| 18 | 0001 | 001 | 540 | 85 | SO | ME | OPEN | E-BAT | IPE-SO-SNF - 41H | So OCB BKR 500 KV (Transm. Dept.) | 136.00 | 2.9 | 4.5 | 405 | 55.00 |
| 19 | 0001 | 003 | 073 | 84 | CE | ME | OPEN | E-BAT | IPE-CE-SEG - COM-MEC | Gen. Battery (Transm.Dest.) | 118 | D | 25000.00 |
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| 29 | 0001 | 003 | 073 | 84 | CE | ME | OPEN | E-BAT | IPE-CE-SVAK - 41H | So OCB BKR 132 KV (Transm. Dept.) | 345.00 | 1.66 | 6.2 | 121 | 573.50 |
| 30 | 0001 | 003 | 073 | 84 | CE | ME | OPEN | E-BAT | IPE-CE-SVAK - 41H | So OCB BKR 132 KV (Transm. Dept.) | 345.00 | 1.66 | 6.2 | 121 | 573.50 |
| 31 | 0001 | 003 | 073 | 84 | CE | ME | OPEN | E-BAT | IPE-CE-SVAK - 41H | So OCB BKR 132 KV (Transm. Dept.) | 345.00 | 1.66 | 6.2 | 121 | 573.50 |
| 32 | 0001 | 003 | 073 | 84 | CE | ME | OPEN | E-BAT | IPE-CE-SVAK - 41H | So OCB BKR 132 KV (Transm. Dept.) | 345.00 | 1.66 | 6.2 | 121 | 573.50 |
ACE (Advanced Computing Engine)

- Groups equipment by aliases in PI Module
- Apply set of equations to groups of equipment
- Generate email notifications or trigger for transfer of measurement docs or creation of notifications
- Event-based and periodic calculations
- Easily turn on or off equations for individual equipment
- 55 class modules and over 6000 contexts
Notification Calculations

- Hydran PPM Rate of Change
- Excessive LTC Operations
- Excessive Runtime Readings
- High Breaker Temperatures
- Breaker Filling Pressure
- High or Low Transformer Oil Levels
- Low Transformer Nitrogen Cylinder Pressure
- Low Transformer Nitrogen Pressure
## Interfacing with Data Sources

- SAP PM Module
- Lab Systems – DeltaX & Doble
- Breaker Diagnostic Data Web Pages
- Transmission SCADA
- Distribution SCADA
- MV-90 13kv Transformer Load Data
- SDC 4-26kv Metering
- Hydran Transformer PPM Monitoring
- SAP PM Measurement Documents
Configuration

The PI System

SAP
- Centralized Data Repository
  - Oil and gas analysis
  - # operations
  - hrs of operation
  - Store all Asset Diagnostic Information
- Analysis Engine
  - Analytical Capability
  - Condition Analysis
  - Counter Based Decisions
- Work Management
  - Create work orders
  - Create alerts (notifications)

OSIsoft
- Reporting Tools
  - Datalink
  - Process Book
- CBM Dashboard
  - using RtWebParts & SharePoint

CGI
- Wireless Mobile Dispatching System
  - Assign work directly to crew

Enterprise License

RtWebParts Drill down capability

VALUE NOW, VALUE OVER TIME
CA Tangible Results

• 2003 Pre-emptive Intervention based on CMMS Oil Diagnostics targeted 16 LTC’s (5 found to have contact problems indicating high potential for major problem)
  – Estimated Cost Saving ~ $300,000
• In 2004 at least 10 LTC’s were drained, maintained and refilled. One of these LTC’s was caught before major damage occurred to the LTC/transformer
• In 2004, 5 Transformers were also targeted and 2 were identified to have major issues
  – Estimated Cost Saving > $1.2M
• 2005 Cost Savings > $2M
Notification Tangible Results

- Problems discovered from CMMS Notifications
  - Controls out of Calibration
  - Leaky Blast Values
  - Incorrect CMV Setting
  - Defective Controls on older LTC
  - Defective Counters
  - Low Oil Levels
  - Cylinder Leaks
  - Hydran PPM

- 2003 Estimated Cost savings for 9 LTC’s and 2 GCB’s is $264,600
- 2004 Estimated Cost saving for 5 Transformers is $800,000
- 2005 Cost Savings > $1M
Conclusion: Proactive Approach Enables:

$ (Million)

Years

Savings

Expected Failures

Corrective Maintenance

Opportunities
Conclusion: Proactive Approach Enables:

- Drive Actionable Results!

Savings are derived from:

- Maintenance Plan Extensions 36%
- Condition Assessment Algorithms 26%
- Counter Based Notifications 39%
### Drill down to details

**PI Point Details**

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#### RT Trend
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- **End Time:** 9/13/2006 0:07:05 AM

#### Max Reading
- **Time:** 08/25/2006 0:00:00 AM
  - **Max:** 89.9988

#### Min Reading
- **Time:** 12/13/2005 1:00:00 PM
  - **Min:** 24.0005

#### Average Reading
- **Time:** 09/13/2006 0:07:05 AM
  - **Average:** 46.1394

#### Standard Deviation
- **Time:** 09/13/2006 0:07:06 AM
  - **Standard Deviation:** 13.6737
Gas and Oil Results
SDG&E
(San Diego Gas & Electric)
RtCBM Program
(Real-time Condition Based Maintenance)
SDG&E RtCBM Architecture

- Microsoft SharePoint Server
  - RtWeb Parts
  - Maintenance PI Server
    - Algorithms
    - Email Alerts

- Operations PI Server

- SCADA

- WiMax/ Wired LAN Connection

16 Port Ethernet Gateway

- Real-time Equipment Data
  - Temperature
    - Winding,
    - Top Oil,
    - LTC
  - Bushing Monitors
    - Phase A, B & C
  - Hydrogen/Water in Oil Monitor
  - LTC Tap Position Indicator

- Non-Scada (Non-Operations) Data
  - On-line Monitors / IEDs

- User Interface and Analysis Tools

- Relational Databases
  - Maintenance System
  - Dissolved Gas Analysis
  - Others
## RtCBM – Data Integration

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<th>Monthly equipment inspections</th>
<th>General asset</th>
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<th>Specific equipment</th>
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<th>System &amp; Engineering</th>
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<td>• Operation counters</td>
<td>• Rating</td>
<td>• Relays &amp; Digital fault recorders</td>
<td>• Operating conditions</td>
<td>• Voltage &amp; Current</td>
<td>• Voltage &amp; Current</td>
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<td>• Alarms, temperature, visual</td>
<td>• Temperature, Pressure</td>
<td>• Age, Type, Design</td>
<td>• PQ Monitors</td>
<td>• Stress factors</td>
<td>• Temperature</td>
<td>• Temperature</td>
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<td>• Functional check</td>
<td>• Voltage</td>
<td>• Operating limits</td>
<td>• Hydrogen in Oil</td>
<td>• Trouble history</td>
<td>• Bushing On-line Power Factor</td>
<td>• Hydrogen in Oil</td>
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<td>• Maintenance data</td>
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<td>• Oil test data</td>
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<td>• Electrical test data</td>
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<td></td>
<td>• Operating speed</td>
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</tbody>
</table>

**Value Now, Value Over Time**
Time-based to RtCBM
- Circuit Breakers

Data Available
- Weekly safety inspections
- Monthly equipment insp.
- Asset Data
- Historical Data
  - Operating conditions
  - Stress factors
  - Trouble
  - Maintenance data
  - Test data (insul & elec)
- Operational data
  - Relays & Digital fault recorders
  - PQ Monitors
- Real-time data
  - Voltage & Current
  - $I^2T$ and Contact Wear
  - Operations Counter

Maintenance Intervals

Planned Approach
Circuit Breaker Operations

Concerns
- Proper fault clearing
- Fault testing with a circuit breaker

Solution
- Verify the health of CB
  - Contact wear
  - Insulation medium integrity
  - Bushings and accessories
  - Operating history
- Use historical and real-time contact wear data (I²T) to make a decision

Substation Relays with Circuit Breaker Monitor

16 Ports Ethernet Gateway

Ops. & Maintenance PI Server

Algorithms
Email Alerts
Transformer at Emergency Rating

Transformer Health Indices

- Insulation Power Factor
- LTC Application & Design
- Oil Conditions
- Bushing & Accessories
- Operating History & Conditions

Paper Insulation Health

<table>
<thead>
<tr>
<th>Location of Paper Sample</th>
<th>Degree of Polymerization (DP)</th>
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<tbody>
<tr>
<td>NLTC – Phase A</td>
<td>586</td>
</tr>
<tr>
<td>NLTC – Phase B</td>
<td>737</td>
</tr>
<tr>
<td>69kV Bushing C</td>
<td>688</td>
</tr>
</tbody>
</table>

New Insulation Paper: \(1000 < \text{DPv} < 1300\)
Middle Aged Insulation Paper: \(\text{DPv} = 500\)
Old Age Insulation Paper: \(\text{DPv} < 251\)
Severely Degraded Insulation Paper: \(\text{DPv} < 151\)
Transformer at Emergency Rating

Comparison of hot spot rise over top oil simulated versus actual

<table>
<thead>
<tr>
<th></th>
<th>Top Oil</th>
<th>Hot Spot</th>
<th>LOL</th>
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</thead>
<tbody>
<tr>
<td>IEEE</td>
<td>105</td>
<td>176</td>
<td>.149</td>
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<tr>
<td>Ptload</td>
<td>105</td>
<td>145</td>
<td>.039</td>
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<tr>
<td>Actual HS rise</td>
<td>106</td>
<td>131</td>
<td>.014</td>
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</table>

Decision: Based on Transformer Unit Health and Real Time Conditions
Summary of RtCBM Benefits

- **Operations Benefits**
  - Avoid potential equipment failure
  - Increase asset availabilities
  - Respond to equipment alarms according to priorities
  - Maximize asset loading capabilities

- **Maintenance Benefits**
  - Early warning and indication to address conditions
  - Reduce overtime on reactive maintenance
  - Minimize equipment outages

- **Asset Planning Benefits**
  - Improve future equipment specification and application to maximize utilization and performance.
More
Customer
Testimonials/ROI
The work initiated by Dofasco’s ICMS system, with the help of the PI Interface, resulted in a complete recovery of mudgun nozzle to tap hole fit, saving the company $1 million per year, for every year the furnace operates past an 8 year campaign. The poor fit between the mudgun nozzle to tap hole, would not have been evident or remedied by the operators, based on existing control room data.
Dofasco’s Change in Maintenance Culture
From 78% to 91% Equipment Availability
“In Blast Furnace #4, we have extended the furnace campaign from 8 years to 15 years, resulting in a savings of $1MM per year, or $7 MM for 7 years. For Blast Furnace #3 we have extended the campaign from 8 years to 20 years, resulting in a savings of $1MM per year, which results in a savings of $12MM for 12 years. The projected savings are $19 MM just for this case...”

Vlad Djuric, Reliability Manager
Dofasco, Canada
Reduce Costs and Improve Quality

Major Measuring Devices
* Thickness Gauge
* Zinc Coating Weight
* Furnace Thermometers
* Tension Meters
* Pin Hole Detector
OSIsoft Enabling Technology
PI Working by Exception

Alert Notification (PI Notification RtAlerts)

Real-time Rule Assessment (PI ACE)

Asset Information Structure (MDB and AF)

Asset Reliability (PI OLEDB and RtReports)

Integrated Asset Information (RtWebParts)

Improve Reliability and Quality
Summary

• Leveraging your investment and resources by utilizing The PI System to provide more value to your organization

• Expanding the benefits from Operations to Engineering, Planning, Protection, Maintenance and Asset Management

THANK YOU!!