Leveraging Historical and Real-time Data to Meet the Challenges of Wind Power Generation
The Primary Challenges

- Asset utilization
  - Availability
  - Efficiency

- Sell power at highest rates
  - Grid integration
  - Forecasting
  - Scheduling
  - Trading

- Warranty management
Other Challenges and Opportunities

- Enterprise integration
  - Heterogeneous assets
- Security
  - NERC CIP
- Regulations and Compliance
  - Reporting
About OSIsoft

- Established in 1980
- Founder - J. Patrick Kennedy
- Private & Profitable
- Headquarters - San Leandro, CA
- 660 + employees
- 225 + employees in product development
- PI Installed base
  - 14,000 + systems (excluding OEMs)
  - 110 + countries
  - 40% of Fortune 1 000 process & manufacturing companies
  - 65% of Global 500 process & manufacturing companies
Primary market segmentation

Asia Pacific: 13%
Europe: 60%
Africa, ME & Eurasia: 27%
Americas: 60%
President of Spain at RED Electrica
12 of Top 15 Owner/Operators use PI*

MW Capacity EOY 2006

- Iberdrola (ES)
- FPL (US)
- Acciona (ES)
- Babcock Brown Windpartner (AUS)
- Scottish Power/PPM (UK)
- Endesa (SP)
- Eurus Energy Holding (JP)
- EDP (Portugal)
- Shell Renewable (NL)
- Essent/Nuon (NL)
- Horizon (US)
- EDF (FR)
- Dong (DK)
- Enel (Italy)
- Vattenfall (S)

Value now, Value over time.
Delivering Value to Wind Customers

- 7200MWs in single WindCORE – going global...
- Centralized M&D Center with Control – coordinated with Grid Operator – RED Electrica

- >5000MWs in Centralized M&D Center
- Distributed Control approach

- Enterprise Customer since 2007
- Developing Operations Center – Bezier, France.
- US Subsidiary – ENXCO – OCC Center - Minnesota

- Enterprise Customer since 2007/08
- Global Integration of NA, European, ME, Asian assets

- Enterprise Customer since 2007
- Distributed control, centralized monitoring & diagnostics
Targeted Industries

- Power & Utilities – 30%
- Oil & Gas – 20%
- Chemicals & Petrochemicals – 10%
- Mines, Metals, Metallurgy & Materials – 10%
- Pulp & Paper – 10%
- Pharma., Food & Life Sciences – 10%
- Data Centers, IT & Facilities (all industries)
Omnipresent Challenges

- Quality
- Personnel
- Variable costs
  - Materials
  - Energy
- Capital utilization
- Trading and markets
- Regulations, compliance
- Environmental, Health, Safety
- Technology
Quick PI System Overview

Value now, Value over time.
Enterprise Architecture

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Basic Connectivity to Turbines

Hardware SCADA

Wind SCADA

OPC Server

Customer Server

PI OPC Client (PI2OPC)

T1 Link

Campbell Logger

OSI Campbell SCIENTIFIC Loggernet

PI DATABASE
Customer Architecture--Iberdrola

DOMINA SYSTEM

- Production Management Server
- SAP Maintenance Management Server

INTERNET

FIREWALL

INTRANET

CORPORATE NETWORK

ROUTER

INTERNET

WAN

WIND FARM

Local Control System

Corporate Network Access System

WIND FARM B

Local Control System

Corporate Network Access System

IBERDROLA RENEWABLE ENERGY O&M CENTER

- Retro projection screen
- iBerinco Historical SCADA + PI System

SCADA #1

HDB #2

SCADA #2

HDB #1

CENTRAL OPERATION CENTER NETWORK

CORPORATE NETWORK

ROUTE

ROUTE

ROUTE

ROUTE

Central Operation Center Network
Challenge--Asset Utilization

- **Availability**
  - Is asset online?

- **Efficiency**
  - Is it performing to expected levels?
## What is Availability Worth?

<table>
<thead>
<tr>
<th>Hours</th>
<th>TurbineClass (kW)</th>
<th>Capacity Factor</th>
<th>Availability</th>
<th>Annual Expected Output (kWh)*</th>
<th>Busbar Price /kWh</th>
<th>Annual Cash Flow per WTG</th>
</tr>
</thead>
<tbody>
<tr>
<td>8760</td>
<td>600</td>
<td>33%</td>
<td>100%</td>
<td>1,734,480</td>
<td>0.0425</td>
<td>$ 73,715.40</td>
</tr>
<tr>
<td>8760</td>
<td>1000</td>
<td>33%</td>
<td>100%</td>
<td>2,890,800</td>
<td>0.0425</td>
<td>$ 122,859.00</td>
</tr>
<tr>
<td>8760</td>
<td>1500</td>
<td>33%</td>
<td>100%</td>
<td>4,336,200</td>
<td>0.0425</td>
<td>$ 184,288.50</td>
</tr>
<tr>
<td>8760</td>
<td>2000</td>
<td>33%</td>
<td>100%</td>
<td>5,781,600</td>
<td>0.0425</td>
<td>$ 245,718.00</td>
</tr>
<tr>
<td>8760</td>
<td>2500</td>
<td>33%</td>
<td>100%</td>
<td>7,227,000</td>
<td>0.0425</td>
<td>$ 307,147.50</td>
</tr>
<tr>
<td>8760</td>
<td>5000</td>
<td>33%</td>
<td>100%</td>
<td>14,454,000</td>
<td>0.0425</td>
<td>$ 614,295.00</td>
</tr>
</tbody>
</table>

*Formula = Hours * Generator Capacity * Capacity Factor * Availability*

- A typical utility scale wind farm may have 30 to 200 Turbines
- Large owners (e.g. Iberdrola – 3500MWs) may have thousands of turbines
- A single percentage point gain/loss of “in-market” availability (e.g. turbines available to operate when the wind is blowing) for
  - Iberdrola **Total Fleet** would result
    - in a 1st Year ROI/loss of **$4.3MUSD**.
    - NPV over 5 Years = **$13.5MUSD** @ 18% Discount Rate
    - Based on US prices, power rate in Spain is .07 to .10/kWh produced
- For a **Single Wind Farm of 150MWs:**
  - In a 1st year ROI of $185,000
  - NPV over 5 years = **$576,000** @ 18% Discount Rate

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Cost reduction in O&M
- By centralizing operation, resource optimization is achieved with a significant reduction of local staff

Reduction of unavailability costs
- Continuous monitoring and remote operation of wind farms
- Remote pre-diagnosis and activation of local maintenance squads for the solution of failures

Implementation of energy control functions
- To meet new grid operation requirements based on high penetration rate of wind energy...

Centralized way to communicate with other energy management centres
Iberdrola WindCORE

- Alarm Warnings and Events
- Advanced Alarm Manager (Multimedia and Squad Manager)
- Historic Data Storage
- Historic Reports
- Calculation
- Reports
### Benefit Received

<table>
<thead>
<tr>
<th>MW</th>
<th>Capacity Factor</th>
<th>Availability</th>
<th>MWh Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>27.5%</td>
<td>97%</td>
<td>4673460</td>
</tr>
<tr>
<td>2000</td>
<td>27.5%</td>
<td>98%</td>
<td>4721640</td>
</tr>
</tbody>
</table>

48180 MWh Gain from Availability Improvement

Feed In Tariff USD/MWh:

|       | $80,00      | $3.854.400,00 |

### Cost Model for WindCORE

- **Total cost**
  - Year 1: $2.100.000
  - Year 2: $600.000
  - Year 3: $600.000
  - Year 4: $600.000
  - Year 5: $600.000

- **Net Present Value of Cost**: $3.638.108
- **Benefit**
  - Year 1: $3.854.400
  - Year 2: $3.854.400
  - Year 3: $3.854.400
  - Year 4: $3.854.400
  - Year 5: $3.854.400

- **Net Present Value of Benefit**: $14.611.209
- **Payout per Dollar Spent**: $4.02

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**Cost Assumptions: Number of Wind Farms**
Availability--Common Component Failures

- Gearbox
- Blades
- Drive train
Event Search Results

Gearbox Example

Value now, Value over time.
Gearbox Example

Value now, Value over time.
<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Hours Lost</th>
<th>Production Lost</th>
<th>Fault</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/5/04</td>
<td>19:15</td>
<td>11.90</td>
<td>6,627</td>
<td>Gen Temp High</td>
</tr>
<tr>
<td>5/9/04</td>
<td>20:29</td>
<td>11.93</td>
<td>7,200</td>
<td>Gen Temp High</td>
</tr>
<tr>
<td>5/16/04</td>
<td>18:25</td>
<td>17.32</td>
<td>10,297</td>
<td>Gen Temp High</td>
</tr>
<tr>
<td>6/29/04</td>
<td>16:14</td>
<td>382.57</td>
<td>157,665</td>
<td>Generator R&amp;R, Gen Alignment</td>
</tr>
<tr>
<td>7/16/04</td>
<td>6:43</td>
<td>1.05</td>
<td>700</td>
<td>Nacelle Reassembly after R&amp;R Gen</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>424.77</td>
<td>182,489</td>
<td>$10,024 lost revenue from 1 turbine over 2 month period</td>
</tr>
</tbody>
</table>

Value now, Value over time.
Gearbox Example

Value now, Value over time.
Next examples are by one of our Engineers

• Done on real customers systems
• Example of getting visibility into what is going on
Turbine Power Curve Analysis

- Turbine: WTG 01
- Start Time: 4/1/2008
- End Time: 4/2/2008
- Average Output: 100.60 kW
- Avg. Exp. Output: 943.22 kW
- Average Offset: -842.61 kW
- Daily Production (kWh): 4658
- Expected Daily Production: 9952
- Daily Revenues: $419.22
- Expected Daily Revenues: $895.70
- Over/Under Production Cost: -$476.49

Expected/Actual Power

Power Offset/Wind Speed

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Value now, Value over time.
Customer—PPM (owned by Iberdrola)

OSIsoft Users Conference, 2007

Uses PI to:

- Manage Fuel
- Deal with many units and wide geographic distribution; often remote locations.
- Normalizes data from several turbine Manufacturers
- Deal with Complexity of markets
## Reliability vs. Availability

### Park Reliability & Availability Month-to-Date

<table>
<thead>
<tr>
<th></th>
<th>As Of: 2007-04-12 11:00:00</th>
<th>Next Execution: 20 mins</th>
</tr>
</thead>
<tbody>
<tr>
<td>RELI</td>
<td>Klondike 1</td>
<td>Klondike 2</td>
</tr>
<tr>
<td></td>
<td>89.54 %</td>
<td>95.31 %</td>
</tr>
<tr>
<td></td>
<td>78.04 %</td>
<td>84.21 %</td>
</tr>
<tr>
<td>AVAIL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RELI</td>
<td>Shiloh</td>
<td>Highwinds</td>
</tr>
<tr>
<td></td>
<td>99.07 %</td>
<td>88.91 %</td>
</tr>
<tr>
<td></td>
<td>96.79 %</td>
<td>91.73 %</td>
</tr>
<tr>
<td>AVAIL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RELI</td>
<td>Col Green</td>
<td>Elk River</td>
</tr>
<tr>
<td></td>
<td>98.01 %</td>
<td>98.71 %</td>
</tr>
<tr>
<td></td>
<td>91.88 %</td>
<td>92.88 %</td>
</tr>
<tr>
<td>AVAIL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RELI</td>
<td>MapleRidge 1</td>
<td>MapleRidge 2</td>
</tr>
<tr>
<td></td>
<td>92.61 %</td>
<td>89.86 %</td>
</tr>
<tr>
<td></td>
<td>89.72 %</td>
<td>89.33 %</td>
</tr>
</tbody>
</table>
PPM (Now Iberdrola)

Wind Portfolio
Wind Gen Total  425

Value now, Value over time.
PPM—Scotty Gilbert

- 14 day forecasts; about best at this time
- 24 hour forecasts—climatology and park data
  - They bank on this—trading is done 24 hours in advance.
  - Supply vs. buy decisions
PPM—Scotty Gilbert

- At end of day reconcile reality with forecast
  - Did you get the fuel predicted?
  - Did you convert to power as predicted?
- Evaluate Market exposure
  - Were assumptions true?
- Imperative to go back and understand and improve.
Scotty Gilbert’s words of wisdom

- Collect all the information
  - True production vs. predicted
  - Evaluate reasons
  - Evaluate where to invest to improve
  - Answer questions in real time.
    - Don’t take weeks to answer the CEO’s questions
- “Have the courage use the historical data to evaluate performance”
Importance of Forecasting

- ERCOT
- Bonneville Power Authority
- UWIG--AWEA
Ramp Event Caught By ERCOT

Ramping Example 1 cont.

Aggregated Wind Output - Evening of July 8th, 2008

Value now, Value over time.
Balancing—Bonneville Power Authority

1,500 MW Balancing Area

19 Wind Farms

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**Value of Forecasting**

GE-NYSERDA Study for NYISO, 10% Penetration, 2005
Operating Costs with Wind Forecasts

- Day-ahead unit commitment considers forecasted wind generation

<table>
<thead>
<tr>
<th></th>
<th>No Wind Forecast</th>
<th>SOA Wind Forecast</th>
<th>Perfect Wind Forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Variable Cost Reduction</td>
<td>$335 M</td>
<td>$430 M</td>
<td>$455 M</td>
</tr>
<tr>
<td>Net Benefit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind Generation</td>
<td></td>
<td>$95 M</td>
<td>$120 M</td>
</tr>
<tr>
<td>Value of Forecast</td>
<td></td>
<td>$10.70/MWH</td>
<td>$13.50/MWH</td>
</tr>
</tbody>
</table>

8900 GWH

Presented by GE at UWIG Sacramento Meeting, Nov. 2005

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Keys—

• Best 1 hour prediction is current conditions.
• Schedule maintenance when wind is likely to be down.
• Real-time data to make better maintenance decisions
  • Final maintenance planning done based on current and immediate forecast
Send to regulators production plan

- Hour to two hours in advance
  - Failure to deliver requires purchasing power
- Forecasting services
  - Feed them your wind data
  - Their models forecast the next few hours
  - Calculate output potential
- Use PI to track forecast accuracy
Based on availability
  • (Often part of O & M contract)
Non-competitive during boom of last few years
  • Owner now has opportunity of doing O & M on day 1
Close monitoring of guaranteed asset provides key knowledge to transition into post warranty mode.
Warranty Management

- Manufacturers provide warranty based on availability
- Availability is natively only found in their SCADA
- PI Acts as the “Fox Watching the Hens”
Resources

- T&D Users Group—fall
Questions? Or can dig into products.
Product Overview
What is PI?

- System that
  - Connects & Collects (streaming data, events, strings, etc.)
  - Archives & Manages (long time at resolution of acquisition)
  - Processes (calculates, aggregates, analytics)
  - Visualizes (thick, thin, portal, web, etc.)
  - Contextualizes (metadata, structure, etc.)
  -Alerts and Notifies (alarm, notifications, messages, etc.)

- Real Time Data & Events
Connect
Collect data from hundreds of sources.

Manage
Gather and archive large volumes of data. Scale to meet your growing business needs.

Analyze
Access real-time or historical role-based data for the entire enterprise at any time.

Present
View data, identify problems, and take corrective action with familiar, easy-to-use graphical tools.

Interfaces

Servers

Analytics

Visuals
The PI System® connects to real-time and event data every second, every minute, every day, and archives it indefinitely.

- Measure and interpret a variety of data
- Both time-series and event data
- Secure access
- From virtually anywhere and any source
- Using time intervals and sampling rates customized to your business needs

*Connect to over 400 data systems and sources out of the box.*
The center of the your real-time data infrastructure.

- Highly-available
- Secure
- Accessible
- Reliable
- Mission-critical, role-based information to make informed decisions

Ensure that everyone has the same information.
The standardized system provides— “one version of the truth.”
The PI System: Manage

PI Data Services
- PI Data Access (PI SDK)
- Relational Data (OLEDB)
- Web Service Data
- Managed Provider

PI Archive
AF Server
- SQL Server

Connect (Interfaces)
Analyze (Analytics)
Present (Visuals)

Manage (Servers)

Value now, Value over time.
Convert real-time data into actionable information (post processing)
  • Equations, calculations and business rules
  • Reports
  • Batch reports
  • Notifications and Alerts

Measure and improve business performance.
The PI System: Analyze

- Connect (Interfaces)
- Manage (Servers)
- Present (Visuals)

Analyze (Analytics)

- PI Advanced Computing Engine
- RtReports
- PI Notifications
- Sigmafine
- PI Analytics (new PE, Alarm, and RTSQC engine)
PI System® Visuals are a configurable suite of intuitive, easy-to-use graphical tools that simplify decision-making.

Decision makers can use familiar desktop tools such as:
- OSIsoft’s PI ProcessBook
- Microsoft Office Excel or Microsoft Office SharePoint Server
- SAP Enterprise Portal

Empower informed decisions and drive business success.
The PI System: Present

Connect (Interfaces)  Manage (Servers)  Analyze (Analytics)  Present (Visuals)

Desktop
- ProcessBook
- DataLink
- DataLink Excel Services
- Manual Logger

Web
- Rt WebParts
- ActiveView
- RtPM Business Package
The PI System: Architecture
The PI System: Architecture

Value now, Value over time.
The PI System: Architecture
Value now, Value over time.
PI System - Simple System

Process Control Secure LAN

Manual Data  SCADA/DCS  PLC / Instrument Systems  LIMS Systems

PI  PI API

Value now, Value over time.
Value now, Value over time.
How PI delivers value...

- Application and industry “Agnostic”
- Value out of the box
- “Fits in place”
- Scalable
  - Small, through medium to large and very large system
  - Simple to complex systems
  - Slow to high fidelity in the data rate (events per second),
  - Low to high intensity of pre and post processing (analytics)
- Preserves operational knowledge of an enterprise
- Enhances the capability of scarce workers
- Reliable and low maintenance by the user (striving to remain)
- Manages both the real time data and its data communications infrastructure - convergence
What is tangible value for Customers?

- Avoided $150 Million in Capital Spending to meet Environmental legislation
- Reduced maintenance costs by 3% and lowered systems management costs by a 3 to 2 ratio
- Saved $20 million in Energy Costs
- Eliminated $12 million in annual recurring energy costs
- Saved $5 per ton in Maintenance costs in Paper Mill operations
What is tangible value for Customers?

- $2.4 million savings in just one chemical plant, in production and maintenance
- Improved controlling over operations gains 41% return in 3.5 years (OEE, KPI’s)
- $1M Reduction of Electricity Costs in First Year
- $5 million benefits from capture of KPI’s and related performance data from operating facilities
- Increased diesel yield earned an $1 million increase in profitability
- Saved over $500,000 in one mill by using PI for real time costing and decision support for operators