Field Demonstration of a Cost-Effective Advanced Monitoring Solution – Deployment of a Predictive Emissions Monitoring System (PEMS) as a Complete Compliance Solution for a Large Cogeneration Facility in the U.S.

Abstract 157

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Definition of PEMS

A PEMS is a software based data acquisition system that is interfaced with the process control system and inputs from the combustion or pollution control process.

It utilizes these inputs to determine the emission rates of the various pollutants that are regulated.

A PEMS has no gas analyzers like a CEMS - Continuous Emissions Monitoring System
Typical PEMS Schematic
PEMS for Compliance with

40 CFR Part 60
NEW SOURCE PERFORMANCE STANDARD
(Performance Standard PS-16 for PEMS)

40 CFR Part 75
TITLE IV ACID RAIN (Subpart E requirements for alternative methods)

Other regulations as alternate to CEMS
Monitoring Primary Pollutants ($NO_x$, $SO_x$, CO) and $O_2$, $CO_2$, VOC, $NH_3$, $H_2S$ etc.

PEMS may be used as an alternative to CEMS for all gas- or oil-fired boilers, ethanol plants, for gas-fired heaters, sewage sludge incinerators and simple or combined cycle turbines.

PEMS are allowed as alternatives to CEMS.
Parametric Systems

- Up to 3 inputs with correlation to emissions
- Simple formulaic approach
- Accuracy is very limited
- Performance will not be the same as CEMS
- Normally over-reports emissions for the source
- Acceptable for peaking units with less than 10% operating time in a year and for flares where site testing is not feasible
- Continuous Parametric Monitoring System - CPMS
Empirical Systems

- Many inputs with correlation to emissions
- Performance can be the same as a CEMS with similar quality assurance
- Collect Historical Training Dataset

Empirical neural network and statistical hybrid PEMS models have been certified by Clean Air Markets Division

- Emission data comes from existing CEMS or RM testing
- Certification and Performance Testing
  - Periodic (annual or quarterly) testing to validate the emission levels at each load point
## PEMS Model Envelope

<table>
<thead>
<tr>
<th>INPUT</th>
<th>DESCRIPTION</th>
<th>MIN</th>
<th>MAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input14*</td>
<td>Mega-Watt Load</td>
<td>0.00</td>
<td>63.9</td>
</tr>
<tr>
<td>Input29*</td>
<td>Gas Flow</td>
<td>0.00</td>
<td>38445.2</td>
</tr>
<tr>
<td>Input10</td>
<td>Guide Vane Position</td>
<td>50.20</td>
<td>84.4</td>
</tr>
<tr>
<td>Input13</td>
<td>Firing Temperature Reference</td>
<td>0.0</td>
<td>1997.7</td>
</tr>
<tr>
<td>Input15</td>
<td>Fuel Stroke Gas</td>
<td>0.0</td>
<td>73.1</td>
</tr>
<tr>
<td>Input17</td>
<td>Fuel Stroke Reference</td>
<td>0.0</td>
<td>74.5</td>
</tr>
<tr>
<td>Input24</td>
<td>IGV Temperature Cont Rev</td>
<td>0.0</td>
<td>1259.9</td>
</tr>
<tr>
<td>Input25</td>
<td>Average Exhaust Temp</td>
<td>74.06</td>
<td>1099.0</td>
</tr>
<tr>
<td>Input3</td>
<td>Bell-mouth Differential Pressure</td>
<td>0.00</td>
<td>68.6</td>
</tr>
<tr>
<td>Input4</td>
<td>Comp Discharge Pressure</td>
<td>0.00</td>
<td>132.6</td>
</tr>
<tr>
<td>Input6</td>
<td>Air Flow</td>
<td>0.0</td>
<td>548.6</td>
</tr>
<tr>
<td>Input7</td>
<td>Air Flow Dry</td>
<td>0.0</td>
<td>546.5</td>
</tr>
<tr>
<td>Input19</td>
<td>Splitter Valve Position</td>
<td>0.0</td>
<td>101.0</td>
</tr>
<tr>
<td>Input30</td>
<td>Turbine Exhaust Press</td>
<td>0.0</td>
<td>16.55</td>
</tr>
</tbody>
</table>
Empirical System Results ($\text{NO}_x$ & $\text{O}_2$)

Oil-fired boiler

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Empirical System Results (CO & CO$_2$)

Oil-fired boiler
## PEMS Periodic Quality Control

### PEMS is an Analyzer!

<table>
<thead>
<tr>
<th>Activity</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor Validation</td>
<td>Every minute</td>
</tr>
<tr>
<td>Zero &amp; Span</td>
<td>Daily</td>
</tr>
<tr>
<td>RAA (versus SRM)</td>
<td>Quarterly in the first year</td>
</tr>
<tr>
<td>RATA</td>
<td>Annually</td>
</tr>
<tr>
<td>Input failure detection</td>
<td>Before RATA</td>
</tr>
<tr>
<td>Bias check</td>
<td>After RATA</td>
</tr>
<tr>
<td>Statistical analysis</td>
<td>After re-training of model</td>
</tr>
<tr>
<td>Input failure alarms</td>
<td>After re-training or RATA</td>
</tr>
</tbody>
</table>

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"Relative Accuracy Test Audit“ Primary method of determining the correlation of CEMS / PEMS data to simultaneously collected reference method test data, using **no fewer than nine reference method test runs**, conducted as outlined in 40 CFR 60, Appendix A.

710 MW Gas-Fired (NG and BFG)

Natural gas and blast furnace gas fired turbines and boilers with existing CEMS.

U.S. EPA Part 75 NO$_x$ Trading, and Part 60 CO and SO$_2$
PEMS Initial RATA Test

Boiler Gas

Test Run

NOx lb/mmbtu

RM
PEMS

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PEMS Initial RATA Test

Combined Cycle Turbine

Test Run

NOx lbs/mmBtu

1 2 3 4 5 6 7 8 9

0.034
0.033
0.032
0.031
0.030
0.029
0.028
0.027

RM
PEMS
PEMS Capital and O&M cost

CEMS vs. PEMS Quality Assurance
Costs about the same

PEMS vs. CEMS Initial Capital Costs
About 50% to 70% of CEMS

PEMS vs. CEMS Operational Costs
About 10% to 30% of CEMS
## Cost PEMS vs. CEMS (Recent Example)

<table>
<thead>
<tr>
<th>System Total</th>
<th>2 PEMS</th>
<th>2 CEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial System Costs:</strong></td>
<td><strong>$166K</strong></td>
<td><strong>$255K</strong></td>
</tr>
<tr>
<td>Including installation costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Annual Costs: per year</strong></td>
<td><strong>$30K</strong></td>
<td><strong>$66K</strong></td>
</tr>
<tr>
<td><strong>Maintenance Costs: per year</strong></td>
<td><strong>$12K</strong></td>
<td><strong>$54K</strong></td>
</tr>
<tr>
<td><strong>Annual System Cost Totals:</strong></td>
<td><strong>$42K</strong></td>
<td><strong>$120K</strong></td>
</tr>
<tr>
<td><strong>Grand Total:</strong></td>
<td><strong>$208K</strong></td>
<td><strong>$375K</strong></td>
</tr>
</tbody>
</table>
PEMS Cogeneration Facility

3 Turbines, 3 Boilers = 6 CEMS Retired

• Initial certification in March 2004.
• 40 CFR Part 75 Subpart E demonstration completed Q3 2004. EPA Administrator approval received Q1, 2005
• This site turned off 6 CEMS in 6 shelters which eliminated over $300,000 per year in operational and maintenance costs!
PEMS Benefits

- Significantly lower capital expenditures
- A fraction the operational costs of a CEMS
- Maintenance and repair costs virtually eliminated
- If a particular parameter is missing, the model utilizes other available parameters for prediction – Hybrid aspect of the model
- Valid for normal operating conditions and during transitional states such as startup and shutdown.
- Accuracy equal to or better than a CEMS
- Resilient to input failures
- Model can be setup by staff onsite or third party consultants
- PEMS can be used to determine the source of excess emissions; diagnostic tool to lower emissions
PEMS Outside the US

- **Asia**: Countries with regulations following US EPA look for PEMS implementation. Examples are Malaysia, Philippines, Korea, Singapore etc.

- **China**: Will become a large market due to the extreme power demand and the large number of suitable power and industrial plants. For China we are looking for partners.

- **Middle East**: Strong activities in the United Arab Emirates and Saudi-Arabia. Many plants do not consider the use of CEMS and want to exclusively apply PEMS.

- **Europe**: Some countries use PEMS in lieu of CEMS like the Netherlands or Ireland. The large EU countries Germany, France, UK, Italy and Spain are starting now. PEMS already applied for small sources < 50 MW (GT).
Leapfrogging

For appropriate sources that need continuous emissions monitoring under an enacted regulation, PEMS can be used in lieu of CEMS.

In case these sources do not have any monitoring, this could save the customer the initial implementation of laborious and costly CEMS before ultimately using PEMS.

Quality of the monitoring results as well as availability could even be improved by PEMS.
Questions?

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