MENA Offshore Platforms 2014
Combining analytics and process automation for enhanced emission control strategies: PEMS at work
Emission Monitoring Systems
The Traditional Approach

- The core of traditional Emission Monitoring System are Hardware Analyzer, integrated with IT and software infrastructure for emission storage and reporting.
- EMS encompasses the following functions:
  - Sampling
  - Analysis
  - Data Acquisition
  - Data Validation
  - Data Processing and Archiving
Introduction
Zooming on CEMS

PEMS, Predictive Emission Monitoring Systems, represent an alternative technology for emission monitoring based on software models. PEMS provide emission estimation by means of sophisticated models based on mathematical and/or statistical techniques. Models are able to exploit the inherent correlation existing between process variables (flow, temperature and pressure) and emission properties ($\text{NO}_x$, $\text{SO}_2$, CO, CO$_2$).

Correlation are assessed and evaluated through field measurement campaigns:
- Emission Data collected from existing HW analyzers or when not available temporarily installed at plant stack
- Process Data from plant Control System (DCS, PLC) or Process Historians
A **SYSTEM** is defined as a *collection of objects* among which it exists a set of cause-effect relationships.

A **MODEL** is defined as a *set of rules* by which, knowing the inputs, it is possible to derive the outputs behaviors.

It is possible to quantitatively represent a system by a model:

\[ Y_i = L_i [x_1, x_2, \ldots, x_s] \quad i=1, \ldots, r \]
Model-based Emission Monitoring
Where does it come from?

- It is possible to classify modeling technique in two main groups:
  - **Fundamental** (or First-Principle) **Models**, where the descriptive equations are derived from the basic physical and chemical laws
    
    **Momentum Balance:**
    
    \[
    \frac{d\rho v}{dt} = - \frac{\partial P}{\partial x} - \rho v \frac{\partial \rho v}{\partial x} + \tau \frac{\partial^2 v}{\partial x^2} - \rho g
    \]

  - **Empirical** (or Data-driven) **Models**, where the models are built through a fitting-like procedure over the plant live data

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Model-based Emission Monitoring
Where does it come from?

- Process Automation Trends in the last 25 years:
  - Wide Spread of Process Computers, Distributed Control Systems (DCS) and SCADA
  - Data Collection and Storage is easy, cheap and straightforward
  - Historical data are a valuable asset for better control, management and optimization
Model-based Emission Monitoring
Rationale for PEMS

- Leveraging and exploiting Process Automation, Analytics and Information Technology to improve environmental monitoring and performances

- Exploiting the wealth of meaningful data available in modern industrial plants to accurately estimate emission levels and deeply understand how they develop and can be reduced
PEMS
Main Criticalities

- PEMS successful implementation requires three main ingredients:
  - **Technology**: i.e. SW environment able to handle data from different sources, build and validate efficient models and endowed with proper facilities for on-line deployment and monitoring
  - **Know-how**: i.e. highly skilled engineering resources able to blend instrumentation and analytics competences with process automation capabilities and modelling building expertise
  - **Local Presence**: in order to provide competitive solutions (and efficient maintenance) service engineers should be next-door
A unique software platform, ABB proprietary, for development and deployment of empirical process models, featuring different technologies:

- Neural Networks
- Statistical Regressions
- Multivariate Statistical Analysis
- Equation-based models
- Custom-based models (DLLs)

It is composed by two different environments:

- The Model Builder for data analysis, model building and validation
- The On-line environment for effective and quick model deployment, execution and monitoring
PEMS: Technology
IMP Model Builder – Features

- Data Import from common sources like .xls, .csv, .txt etc.
- Data pre-processing: Automatic Outlier Removal to clean dataset for modelling from anomalous process data
- Correlation and PCA: specific advanced statistical techniques to identify best process variables influencing emissions or quality variables
- Modeling functions are provided by proven, field-tested, latest generation routines
- Model development executed through Wizards, to optimize manpower allocation
- Model Explorer extends use of models beyond on-line utilization (“What-if” analysis)
PEMS: Technology
IMP On-line: – Features

- Quick and effective real-time implementation on different DCS through OPC
- Supports multi OPC connection to gather data from different sources
- Configurable filtering of inputs and outlier removal strategies to verify and evidence abnormal process condition and bad quality data
- Emission estimation visualization, trending and storing capabilities
- Direct connection to Laboratory Information Management Systems
- Direct connection with Data Acquisition System
- Built-in functions for periodic recalibration (Bias calculation)
Inferential Modeling Platform Installations
Primary Source of Emission Monitoring
- Where CEMS are not feasible or cost-effective

Back-up/Validation of Existing HW Analyzers
- Coupled with traditional CEMS to increase the availability of the Emission Monitoring System up to 99.5%
PEMS typical general requirements are:

- Plant has to be instrumented (T,F,P sensors) and automated (PLC or DCS presence)
- Quality of combustion fuel has not to vary too much or has to be monitored

PEMS can be ideally applied to every combustion process across the industry sectors from O&G, Chemical & Petrochemical to P&P, Cement, Metal, Power Utilities.

PEMS perfectly fit in Gas Turbine applications (Power, Compressor Drivers), Large Industrial Combustion Engines, Boilers and Furnaces.
PEMS Application
Typical SW Architecture (Back-up to HW CEMS)

Analyzer Values

IMP

Predicted Values

∑
discrepancy between measured and predicted values

“maintenance trigger”

FIELD

Process Variables

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Indication of maintenance need

- Physical sensor drift from model: by detecting the drift, maintenance needs can be anticipated; maintenance activity can be validated by using the model.
PEMS Application Project Execution

Data Collection → Data Processing → Inferential Model Building and Testing → Model Validation → Final Assessment & Commissioning

Office Activities

On Site Activities
PEMS Success Story #1
Gas injection compressor units

- Twin trains of gas compression
- Compressors gas turbine driven, each GT emission to a dedicated chimney
- Two stage for each train (high and low pressure)
- PEMS installed at each stack (4 system)
PEMS Success Story #1
Plant EMS: Hardware/Software architecture

**EMS Server:** Third party
**EMS Client:** ABB PGP

**EMS Client:**
- Collects data from DCS and make those available to IMP On-Line trough OPC Protocol.
- Collects Prediction from IMP On-Line trough OPC and trough Modbus send to EMS Server

**EMS Server:**
- Collects data from EMS client and CEMS analyzer at stack
- Send data to Company HQ

New Cabinet-Control room

EMS Server-Durag

ABB IMP Online ABB PGP

Plant LAN

DCS Ring- Infi 90 Bailey

DCS System Bailey Infi90
Connection to DCS ICI03
Connection to EMS Modbus
PEMS Success Story #1

Conclusions

- Commissioning successful completed by May 2008
- It has been achieved the international certificate EPA (US Environmental Protection Agency)
- First ABB commercial solution for an emission monitoring system based on Software Sensors, EPA Certified, in O&G field in Middle East Region.
- Fully Integrated in the plant base automation system
- A paper published on ABB review
- 2013: major maintenance and recalibration completed
PEMS Success Story #2
Mediterranean Region Major Refinery

- Project includes the supply of PEMS for three stacks in a refinery in Mediterranean and inclusion in the existing EMS

- Customer wanted to
  - Increase CEMS service time to meet tighter regulation
  - Prove the viability of PEMS technology to local environmental legislator, pioneering the first application in the country

- Site Selection
  - Refinery is one of the biggest in Europe and has a production capacity of 180,000 bbl/day.
  - PEMS are integrated in the existing EMS and act as back-up to increase traditional CEMS availability for the three below plant units
    - Sulfur Recovery Units (SRU)
    - Fluid Catalytic Cracking Unit (FCCU)
    - Belco Plant

- Emissions and properties estimated:
  - Flue Gas flow, CO, O₂, SO₂, NO, Particulate
Characteristics:

- 3 parallel trains with different layout
- 3 feed gas with variable composition, coming from several different plant units:
  - SO₂ rich gas (SRG)
  - Sour water gas (SWS)
  - Amine acid gas (AAG)
System includes:

- 3 EMS client collecting emission data from stack analyzers
- 1 EMS server for emission data reporting and storage for the whole refinery
- 1 PEMS server
- 1 PIMS server collecting data from different DCS
La discrepanza, il BIAS calcolato e il BIAS approvato vengono aggiornati all'attivazione dei rispettivi bottoni.
Il bottone di RESET permette l'azzeroamento dei loro valori: questa operazione è consigliata quando
la discrepanza e i BIAS vengono resettati nel software IMP nel Server dedicato.

Salva
PEMS Success Story #2
PEMS Results: FCC

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PEMS
CEMS
NO Predictions and measured values in a 1-day span for the FCC unit
PEMS
Conclusions

- PEMS are a cost effective solution to complete and enhance emission monitoring strategies.
- PEMS features distinct advantages in a number of applications with or without HW analysers
- ABB has the experience, the technology and the qualified local presence to provide the best solution no matter it is a HW-based CEMS, a PEMS or a smart and flexible combination
- ABB owns IMP, a software tool recognized for PEMS development and deployment which has already a few approved (and certified!) installations.

ABB also offers PEMS solutions. Inferential Modeling Platform (IMP) is proprietary software that is used to develop a reliable model for predictive emission monitoring. IMP can use range of techniques such as neural network, genetic algorithms, multiple linear regression, and calculation script. IMP is loaded on a PC and it communicates with DCS containing process variables and analyzer data. The output can be received by either a dedicated HMI or DCS interface.

Source: WW Emission Monitoring report- ARC 08/12
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