PEMS: The Low-cost Alternative To Emissions Monitoring

Real-world experience with installing and using both PEMS and CEMS at this methanol manufacturing facility is shared. The advantages of PEMS are many

FIGURE 1. This photo shows the methanol production facility of Arrazi in Saudi Arabia

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Regulatory authorities around the world require continuous emissions monitoring of certain pollutants from large combustion sources. There are two main technologies for monitoring these emissions on a continuous basis — one relies on sampling and analyzing exhaust gases from a continuous emissions monitoring system (CEMS); and the other relies on software that uses mathematical algorithms and equations to predict emissions levels from existing control-system data. This second system is called a predictive emissions monitoring system (PEMS).

In this article, practical experience and details of installation of both CEMS and PEMS at the reformers and boilers of the Arrazi methanol manufacturing complex are presented. The real-world experience gained in about two-and-a-half years of operation is shared and can be used as a template to implement PEMS at any site.

THE MANUFACTURING SITE

The experiences described in this article are those of the Arrazi Saudi Methanol Co., an affiliate of Sabic (www.sabic.com), and the world's largest methanol manufacturing complex, located in Jubail, Saudi Arabia (Figure 1). Arrazi uses natural gas, both as fuel and as a raw material to produce grade AA methanol with a purity of more than 99.99%. The site has six reformers, ten boilers, two incinerators and two preheaters.

The environmental performance at Arrazi is regulated by the Royal Commission for Jubail and Yanbu (RCJY) and the Presidency for Meteorology & Environment (PME), which can be considered to be the equivalent to the U.S.'s Environmental Protection Agency (EPA). The Royal Commission Environmental Regulations (RCER) rely heavily on the EPA for guidelines. As per RCER, Arrazi is required to continuously monitor NOx emissions from combustion sources, namely reformers and boilers.

The reasons for why NOx is monitored on a continuous basis is a huge topic in itself and beyond the scope of this article. Here it will just be mentioned that NOx can cause serious environmental problems (such as acid rain), and regulatory authorities in almost all countries require around-the-clock monitoring of NOx from combustion sources.

CEMS VERSUS PEMS

As mentioned earlier, there are two basic ways to continuously monitor emissions: a hardware-based continuous emissions monitoring system (CEMS); and a software-based predictive emissions monitoring system (PEMS). The EPA and the RCJY approve both CEMS and PEMS.

CEMS

CEMS consists of specific hardware — installed on combustion equipment stacks and in the field — that collects samples of exhaust gases and then analyses them to report the "real" emissions levels. A typical hardware-based CEMS consists of the following major parts: analyzer, sample handling system (which includes pumps, chillers, heated sample line and so on), flow-monitoring hardware in the stack, analyzer house, air conditioner, calibration gas cylinders and more. In addition to all of this, the CEMS also contains a data acquisition system (DAS), which stores the data gathered by the CEMS analyzer. A DAS is basically a computer running software that is specially designed for data acquisition and reporting.

PEMS

PEMS consists of software in a dedicated computer that collects data from the plant's existing control systems (for example a distributed control system) and uses mathematical algorithms and equations to "predict" emissions levels. The only piece of hardware that a PEMS requires is a dedicated computer. Details of how PEMS works can be found elsewhere, so here is just a short summary: Simply put, PEMS is a computer model that is capable of predicting the outcome of a "known" process (in other words if the input of a

FIGURE 2. PEMS was implemented on the boiler stacks at Arrazi, three of which are shown here

FIGURE 3. One of the requirements of the PEMS was that it needed to be compatible with the DCS or PLC used for plant control and operation

dynamic and live process is known). By using a sophisticated computer model, the dynamic and live output can be predicted fairly accurately. For emissions monitoring, this "known" process is combustion. (For more on PEMS, see The Maturation of a Technology: Predictive Emissions Monitoring, *Chem. Eng.*, July 2006, pp. 50–55.)

CEMS EXPERIENCE

In 2006, to meet the Royal Commission Environmental Regulations for continuous emissions monitoring, we installed traditional, extractive-type CEMS analyzers for NOx and CO on three of our reformers and one incinerator. This was Phase-1 of a CEMS installation at our site.

The hardware-based CEMS was supplied by a well-known German vendor, and was commissioned in 2007. Our experience with the CEMS installation and subsequent usage brought its strengths and weaknesses to light.

The biggest strength of the CEMS was its ability to report "actual" analyses, regardless of any upstream process (namely feed composition) changes. If the analyzer was calibrated properly, those analytical results were guaranteed to be accurate to within +/- 2.5%.

The biggest weakness of the hardware-based CEMS turned out to be its low service factor and an average downtime of more than 40% during the initial months. The service factor improved over the next two years, but keeping the average cumulative service factor above 80% was a continuous struggle. (The regulations require an uptime of more than 95%.) With a dedicated, CEMS-analyzer-maintenance crew, the service factor could have been improved further. This reflects the simple logical conclusion that the more parts a system has, the more often it is prone to fail.

Furthermore, the running cost of extractive CEMS was high due to maintenance, manpower and energy requirements. Based on this experience, we knew that the total cost of operating the CEMS would grow higher as the number of CEMS installations at the site increased.

All of this inspired us to search for a more economical alternative for CEMS. The answer to this quest came from U.S. EPA regulations, which discussed an alternative method to the CEMS. That alternative was the predictive emissions monitoring system.

PEMS EXPERIENCE

The technology of PEMS has been around in one or other form since the 1980s. The first commercial installation was done in 1992 and was subsequently approved by the EPA in the same year. Since then, hundreds of PEMS have been installed around the world and this technology has seen continuous growth and acceptance.

Installation

As our site approached the second phase of continuous-emissions-monitoring installations, our research led us to decide to install a PEMS instead of a hardware-based CEMS on our seven boilers (Figure 2).

Gaining acceptance. The chemical process industries (CPI) are typically resistant to embracing new technologies that have not been tried and tested for a long time — our site was no exception in this regard. We ran into some resistance at our plant about whether or not PEMS would work. Even after a couple of detailed presentations about PEMS, the skepticism didn't die completely. We knew that the technology had to be proven, just like in the old proverb "the proof of the pudding lies in eating".

The senior management of our company was convinced about the potential of PEMS and directed us to proceed with its installation at our site, hence we started the work on this project. We came across many vendors who could provide PEMS and we wanted to be careful to choose the right vendor, since this was a new technology for us and the Gulf Cooperation Council (GCC) region as a whole.

Vendor selection criteria. The toughest part was to identify the vendor who was right for us. We thoroughly researched various existing PEMS installations worldwide, pinpointed the weaknesses that other PEMS' had and then developed strict criteria for vendor selection. According to our guidelines, the PEMS to be selected by us needed to have the following characteristics:

- Installations in the U.S. that must be certified by the U.S. EPA
- At least 5 of the installations must each be certified as per 40CFR60 and 40CFR75
- There should be no recurring license fees for PEMS/DAS software and all licenses should be perpetual in nature
- The PEMS model should be open and fully configurable by the end user with no support required from the original vendor later on

- The PEMS model must not use any humidity sensors (these sensors are prone to drift and require frequent calibration)
- The PEMS must be able to perform accurately with a minimal amount of stacks testing data

The reason for developing these stringent guidelines was that we didn't want to be stuck with a PEMS that was vendor specific or proprietary, and we wanted a system that was very reliable and robust with no hidden costs. The above criteria ensured that we chose the best possible product. As a result of using these guidelines, we chose a statistical hybrid PEMS model provided by an American vendor.

The regulatory criteria of the EPA require an accuracy of 10%, whereas our chosen vendor promised an accuracy of 5–6%. After commissioning, our PEMS was giving accuracy in the range of 4–6%.

Implementation

For the PEMS to be successfully installed at the Arrazi site, the following were the mandatory pre-requisites:

- Compatibility with the plant's distributed control system (DCS) or programmable logic control (PLC)
- Initiating an analyzer maintenance program (if one did not already exist) at the site
- High speed (preferably > 500 kbps) internet access to the PEMS server for remote support from the vendor
- Availability of remote connection (such as VPN) to the PEMS server

The project execution involved the following main steps:

1. Formation of a project team that included an environmental engineer, DCS control engineer, IT engineer, PEMS vendor specialist and DCS vendor specialist
2. Site survey by vendor to establish site-specific data
3. Installation of the PEMS server and connection to the OPC server. The DCS vendor supported this connection
4. Ensuring trouble free and reliable communication between the PEMS and the OPC server
5. Developing the PEMS model and selecting the input parameters for the PEMS model
6. Stacks testing to fine-tune the PEMS model. (We used a Horiba PG-250 for our stacks testing with a stand-by analyzer available all the time)
7. Pre-RATA (relative accuracy test audit) to verify the predictions of the PEMS model
8. RATA verification by a regulatory agency (Figure 4)
9. Report generation by the data acquisition system (DAS; Figures 5 and 6)

FIGURE 4. An onsite PEMS inspection and relative accuracy test audit (RATA) were conducted by regulatory agencies

FIGURE 5. This typical DAS reporting screen shows the status of all input parameters for one of the seven boilers. The green boxes at the bottom of the screen show that six of the seven boilers are running and one is shut down

The PEMS has been successfully operational at our site for about two-and-a-half years. It was certified and approved by the Royal Commission for Jubail and Yanbu.

Benefits

Once the project was completed and running for over a year, we realized the following main benefits by using a PEMS instead of a CEMS:

- Capital savings of more than 50%
- Almost all CEMS installations are hazardous locations requiring classified explosion-proof equipment (for example Class-1, Div-2) which increases the cost of the CEMS tremendously. By choosing a PEMS we avoided the use of any field-mounted hardware and saved a lot
- Operational cost savings of approximately 90%
- The air conditioning, heated sample line, analyzers, sample conditioning system and so on used in a CEMS are all energy intensive and increase operational costs. A PEMS uses only a computer for running, hence huge savings were also realized in this area
- Maintenance cost savings were approximately 90%
- With a complete absence of the hardware required for CEMS, there was no maintenance to be carried out for PEMS. Again it turned out to be an area of immense savings
- Manpower cost savings of approximately 90%
- The hardware of a CEMS requires dedicated manpower and analyzer

FREQUENTLY ASKED QUESTIONS ABOUT PEMS

During the implementation of the project and even now, the Arrazi team has received many inquiries about its PEMS installation. Some of the most commonly asked questions are shared here:

Q: Does the U.S. EPA approve PEMS?
A: Yes, PEMS is approved by the U.S. EPA.

Q: Can PEMS be used for every combustion application?
A: No, there will always be sources that can only have an extractive CEMS, such as incinerators burning hazardous waste of hugely varying composition.

Q: What is the accuracy of a PEMS?
A: Well-designed PEMS are accurate to within 5–6%. Their accuracy improves with time as more and more operating data are fed into the PEMS model, increasing accuracy to 2–3%.

Q: What are the limitations of a PEMS?
A: PEMS can only predict what it has been "trained" to do. It can't work outside of its "training" envelope. In other words, it can't accurately predict if you are operating outside of the operating parameters that were initially fed into the model.

Q: If PEMS is such a good technology, why isn't every site in the world replacing their CEMS with it?
A: CEMS has been around for over 30 years and so is well known. PEMS is a "relatively" new technology and is catching up fast. We expect to see it more once awareness about it increases.

FIGURE 6. The summary status of all crucial boiler parameters can be displayed on one page

technicians. A PEMS requires no such dedicated support

- Uptime of more than 98%
- With no pumps, heated lines, air conditioners, sample conditioning system or analyzers, the PEMS had almost nothing which could go wrong
- Short project time. The whole PEMS project was completed in less than 6 months as opposed to over a year for the CEMS

Problems

During our almost two-and-a-half years of operation, we faced only the following two problems:

Problem 1: The PEMS server locked-up (hanging), requiring a reboot. This happened a few times during the project implementation and commissioning phase. Once the cause was addressed (remote VPN connection problem and configuration error), the problem never recurred. After the project execution was completed and handed over to us, we never experienced this problem and the PEMS ran without a glitch thereafter.

Problem 2: There was communication failure between the PEMS server and the DCS/OPC server. Infrequently (approximately every two to three months) whenever our IT personnel uploaded any major updates to the OPC server (which required a reboot of the OPC server), the communication between the PEMS server and the OPC server failed. As a result, the PEMS server stopped reporting the emissions. This problem, though not caused by the failure of the PEMS server itself, still caused a loss of data-gathering capability until the OPC settings could be fixed. To address this, we have put procedural and software controls in place to ensure that whenever the OPC software is updated and the OPC server rebooted, the correct settings of the OPC server should be insured by IT to avoid the communications failure and subsequent data loss.

What we would have done differently. If given a chance to redo the whole project again, we would probably change only one thing, the DAS. The existing DAS we are using is not based on MS Windows. Almost all contemporary software are now Windows-based and hence offer many of the features and functionality that we take for granted. We had to work with our DAS supplier to have some functions specially provided for us, and this would have been easier to tailor with Windows-based software.

FUTURE OF PEMS

Our confidence in PEMS has found firm footing after almost two-and-a-half years of trouble-free operation. In contrast, the CEMS has been pretty demanding in terms of maintenance. We are already reviewing the proposals to replace the existing CEMS with a PEMS. ■

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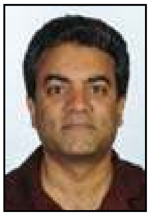

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