

# MATLAB AS A TOOL FOR FOSSIL FUEL POWER PLANT COMBUSTION CONTROL

*P. Jakoubek, L. Hanzal, K. Křehlik*

I&C Energo a.s.

CTU Prague

## Abstract

**MATLAB is commonly used neither as a programming interface for control algorithms implementation in real operating conditions nor as a graphical interface for operators to ensure an easy understandable means to implement their process intervention.**

**The reasons for such a reality are quite obvious. A robust control of real processes, where failures of the operating systems can cause some equipment damage, which can lead to a significant loose of money or to a serious risk of injury for operating staff, cannot be provided by programs running under MS Windows OS. One can encounter on a number of other limitations during the programming and on-line process controlling.**

**However for PhD students who are familiar with MATLAB and who need to employ of some strong programming tool for newly invented algorithms implementation and for their testing in a real environment, MATLAB is the appropriate solution and is widely available for academic utilization.**

**In this paper we present two applications of on-line control algorithms and process parameters monitoring systems programmed in MATLAB with the help of the Graphical User Interface (GUI). The objective of both applications is to reduce emissions of pollutants in flue gasses in fossil fuel power plants by intelligent controlling. Newly invented algorithms for flue gas emissions optimization work online in closed loop with the real system. Communication (process data access and control action uploading) between the real system and the emission optimization systems is the basic assumption for proper function.**

**The OPC protocol, which in MATLAB is implemented by the OPC Toolbox, is used for communication between MATLAB and SCADA systems in both pilot projects. In the first case the SCADA system ZAT-E communicates with MATLAB through the DA server FSGateway in combination with the products of Wonderware. In the second case the OPC server is a part of the SCADA system FOXBORO.**

## 1 Fossil power plants and means to their emission restriction

The power produced by fossil power plants represents about 66% of all produced power in the Czech Republic [5]. That means 54789 GWh/year [5]. The Fossil power plants, which are currently in operation, were constructed mainly between 1950 and 1980.

A small percentage of them were shut down and the rest was partially reconstructed and completed by ecology friendly technologies, resulting in SO<sub>2</sub> and fly-ash emissions reductions by 90% and NO<sub>x</sub> emissions reductions by 50% in the 1990's [5].

Most of the NO<sub>x</sub> emissions reducing measures were made as primary measures, which represent process, technology and construction changes that may prevent the actual forming of thermal NO<sub>x</sub>.

The secondary measures, which support the inhibition of already created NO<sub>x</sub>, were not widely used most probably because of their high acquisition costs.

Currently the NO<sub>x</sub> emissions in most of the fossil fuel power plants vary between 300 and 500 mg/m<sup>3</sup>, which is a considerable reduction in comparison to the past decades. These emissions however

still exceed the future limits, coming into effect in 2016, setting the NO<sub>x</sub> emissions limit to 200 mg/m<sup>3</sup>.

One possible solution to the above defined problem is to invest money in the secondary measures technology implementation.

Another very interesting and challenging solution is to try to get the primary measures closer to the processes and power plants limits using advanced techniques of combustion control.

To set the control process exactly to a power plant's conditions, the combustion model (emissions model) proves to be useful.

There have been many systems developed for power plant emission optimization. Some of them are based on mathematical and physical modeling, others utilize neural networks or other black box methods of identification [2], [3], [4], [5], [6].

## **2 Applications**

The system for the NO<sub>x</sub> and CO emission optimization has been developed utilizing black box identification [1] and other specific computational operations and algorithms.

MATLAB has been chosen for the system programming and process simulation. After the simulation phase an interface for the final real operation testing application had to be chosen. The first possibility was to utilize the system programming interface in the power plant, where all the algorithms were implemented. This possibility encountered the power plant safety rules, which enable just a few engineers to modify power plant control algorithms.

The second possibility was to program the system in some new environment, where our IT engineers were able to work, which means engaging new people who would have to communicate with the system authors and this communication could be very limiting and time demanding.

The third possibility was to use MATLAB for the further programming and implementation of the testing application under the assumption that such an application is worth testing, but not for the real operation on-line closed loop autonomous system.

The third possibility has been chosen for two applications on two different fossil fuel power plant boilers.

The control algorithms were implemented in a common m-file. With the help of the OPC Toolbox real-time data are loaded into the systems and computing algorithms provide the action, which substitutes just some parts of the current control system. The connection and disconnection to the present control system is utilized by signals implemented in the present control system. The signals switch the sources of the desired values of the particular actuators between the present system and the MATLAB pilot application.

## **3 Graphical Interface**

To control the process most efficiently, both pilot applications were implemented in MATLAB Graphical User Interface (GUI). An example of the first application is shown on figure 2. An example of the second pilot application is shown on figure 2.

The GUI ensures a programming tool for a user-friendly H/M interface implementation, which is important especially during the real-time process control, when every process intervention has to be intuitive and straightforward so that power plant operators, who haven't been participating on the system development, can realize their process supervision.

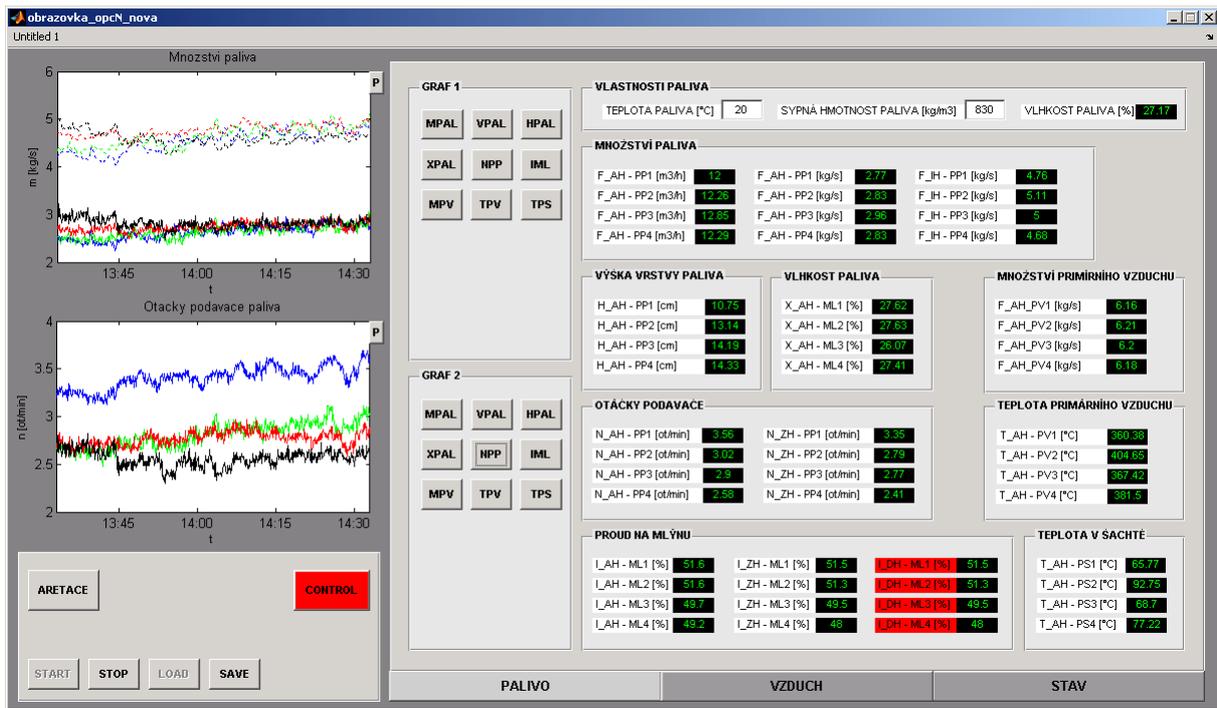


Figure 1: GUI screen of the first pilot application

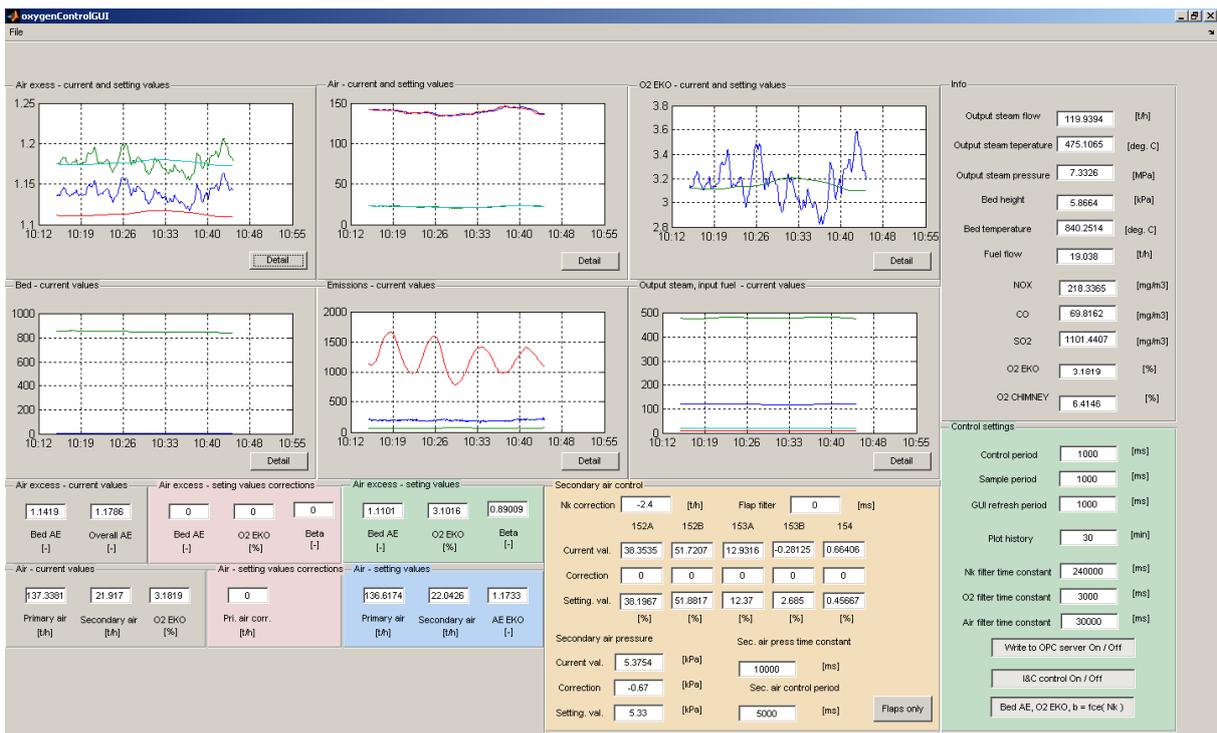


Figure 2: GUI screen of the second pilot application

## 4 Communication

One of the most complicated problems to solve was to find the appropriate manner for the communication between the process and the control system. In MATLAB, one has the possibility to utilize the OPC (Ole for Process Communication) protocol. The OPC protocol has been chosen for its implementation simplicity, for its standardized interface between the client and the server, for its implementation in the most of the control systems and for its easy data verification by external applications.

The OPC protocol defines a number of the data transfer specifications: the OPC DA for the real-time data transfer, the OPC HDA for the historical data transfer, the OPC AE for alarms and events, the OPC BATCH for the batch data transfers, the OPC XML for the XML data transfer, the OPC DX for the data exchange or the recently developed OPC UA for the multiplatform utilization.

In MATLAB one can employ just the most widely utilized one, the OPC DA, which makes the real-time data reading and real-time data writing possible, providing the real-time data time stamp and the signal quality.

In the case of the first application MATLAB communicates with the control system ZAT-E, which includes ZAT and Wonderware technology. The interface between the MATLAB and the ZAT-E control system is utilized by the Wonderware FSGateway DA server, which employs the proprietary protocol Suitelink for the communication with the control system and the OPC DA for the communication with the client (MATLAB).

In the case of the second application the MATLAB pilot application is connected directly to the control system FOXBORO, which includes the OPC server "FOXBORO AIM OPC".

The communication between the MATLAB and the control system can be ensured by a relatively simple control system intervention.

## 5 Results

The algorithm and graphical user interface implementation was not complicated job. It was limited to programming and searching for the appropriate transparent screen composition. Some problems can appear in later stages of the system development.

Difficulties and problems encountered while programming algorithms, implementing communication and while controlling the real process:

- OPC Toolbox 1.0 error (Previously freed memory has been modified),
- seldom MATLAB instability,
- transfer function set point begins at zero,
- limitation in first order filter construction.

On the basis of the six month long experience with application programming and testing, one can submit that MATLAB is a user friendly tool with a large number of functions and libraries, which help the technology analyst to realize his ideas.

## References

- [1] P. Jakoubek, M. Hofreiter, L. Bouda: *New Aspects of Automatic Control, Modelling & Simulation*. Probabilistic approach to NO and CO emission modeling. 12<sup>th</sup> WSEAS International Conference on Automatic Control, Modelling & Simulation (ACOMS'10) ISBN: 978-954-92600-1-4. Europment Pŕes, Sofia, Bulgaria, 2010.
- [2] Zheng L., Shuijun Y., Minaggo Y.: *Monitoring NO<sub>x</sub> Emissions from Coal-Fired Boilers using Generalized Regression Neural Networks*. 2008 IEEE, 978-1-4244-1748-3/08
- [3] Li K., Thompson S., Wieringa P. A., Peng J.: *Neural network and genetic algorithms can support human supervisory control to reduce fossil fuel power plant emission.* , Springer-Verlag London Limited, 2003, DOI 10.1007/s10111-002-0107-6
- [4] Spinelli W., Piroddi L., Li K.: *Nonlinear modeling of NO Emissions in coal-fired power generation plants*. 43<sup>rd</sup> IEEE Conference on Decision and Control, 2004, 0-7803-8682-5/04
- [5] Mühlhaus R., Görner K., Pollack M., Moll W., Pfipsen K.: *Neuronale Netze für die Prozessoptimierung*. VDI-Gesellschaft und Energetik, Tagung „Entwicklungslinien in der Energie- und Kraftwerkstechnik, 1999, VDI-Berichte Nr. 1495 (1999), S. 493-501
- [6] Reinschmidt K. F., Ling B.: *Neural Networks with Multiple-State Neurons for Nitrogen Oxide (NO<sub>x</sub>) Emission Modeling and Advisory Control*. IEEE, 1994, 0-7803-1901-X/94

---

Pavel Jakoubek  
Podnikatelská 553  
19011, Praha 9, Česká republika  
tel.: 725850278  
email.: [pjakoubek@ic-enrgo.eu](mailto:pjakoubek@ic-enrgo.eu)  
[pavel.jakoubek@fs.cvut.cz](mailto:pavel.jakoubek@fs.cvut.cz)

Luděk Hanzal  
Podnikatelská 553  
19011, Praha 9, Česká republika  
tel.: 602758204  
email.: [lhanzal@ic-enrgo.eu](mailto:lhanzal@ic-enrgo.eu)

Karel Křehlík  
NPP Dukovany  
67550, Dukoavny, Česká republika  
tel.: 724143549  
email.: [kkrehlik@ic-enrgo.eu](mailto:kkrehlik@ic-enrgo.eu)