Advanced SCR Control for Dynamic Ammonia Distribution

Scott A. Boyden
ALSTOM Power, Environment Control Systems, 1409 Centerpoint Blvd., Knoxville, TN 37932
E-mail: scott.boyden@power.alstom.com; Telephone: 865.670.4497; Fax: 865.694.5201

Stephen Piche, PhD
Pegasus Technologies, 8200 North Mopac, Suite 230, Austin, TX 78758
E-mail: spiche@pegasustec.com; Telephone: 512.241.3080; Fax: 512.241.3085

Larry Czarnecki
ALSTOM Power, Environment Control Systems, 1409 Centerpoint Blvd., Knoxville, TN 37932
E-mail: larry.czarnecki@power.alstom.com; Telephone: 865.670.4446; Fax: 865.694.5201

Summary

Key performance indicators for Selective Catalytic Reduction units (SCRs) include NOx removal efficiency, ammonia slip, and ammonia utilization. These values are impacted by the reaction conditions. Of particular interest is the profile, or distribution, of the NOx and ammonia in the inlet flue gas. An ideal, or balanced, profile would have the same NOx:ammonia molar ratio at all cells in the SCR. Unfortunately, the world inside the SCR is not ideal and this raises some important questions:

- How important is the NOx:ammonia profile distribution?
- What is the impact of process noise (within design tolerances) on the distribution?
- How does the typical SCR process control system respond to mal-distribution and process noise?
- Can the additional of an advanced process control system improve unit performance?

Experimentation on an operating plant is difficult because of the impact on normal operations, the cost of special instrumentation, and the inability to control and repeat operating conditions. So, a dynamic SCR simulation was constructed in order to begin to address these questions in a rigorous manner.

It would be wonderful to have a dynamic simulation of the entire power plant from the coal mill through the burners, tubes, economizer, ductwork, ammonia injection grid (AIG), SCR and additional back-end air pollution control equipment. Unfortunately, that dynamic simulation is not available. So, it was necessary to construct a new dynamic simulation of just a portion of the fuel-side of the power plant. The scope of the simulator has been set by the trade-off between performance requirements (items such as model fidelity, system boundaries, and user interface) and available development resources. The scope of the SCR simulator has been limited to the necessary elements required to provide sufficient fidelity to answer the immediate research questions. The simulator has been developed using a modular architecture to facilitate expansion and/or re-use of the simulator in future studies.

The SCR simulator includes the following elements:

- Flue Gas “Generator” with Process Values
- Flue Gas Instrumentation Array
- Ammonia injection “grid” with ammonia flow control
- SCR with Process values
- SCR outlet Instrumentation Array

First principle process models with dynamics and appropriate process and instrumentation dead-time have been constructed for the simulation elements. The process control schemes in the simulator utilize typical process instrumentation, however, the simulation environment has a much greater degree of profile resolution to facilitate the study of process noise and different process control schemes.

Mal-distribution of inlet NOx is critical to this control study, so the cross-sectional area of the duct and SCR has been divided into 100 squares of uniform size in a 10x10 grid. The simulation environment manages separate reaction conditions for each

of the 100 squares. The 100 squares allow for a significantly higher degree of observation resolution than can be realistically obtained in a physical system.

In order to manage the simulation, both a "bulk" value and a "distribution profile" are used for the key process inputs. The "bulk" value is the overall property. The distribution profile is a collection of ± offsets from the "bulk" value. This allows for independent, yet coordinated, adjustment of the average/bulk conditions as well as the distribution.

One of the main objectives of the study is to compare the performance of the different control schemes and system configurations. To accomplish this objective, each test case (combination of system configuration and control system) was run on the simulator from a fixed starting point through a set of operating changes. The results (bulk conditions, and summary of the simulation squares) were recorded and summarized in time-series plots and in a statistical table. The operating changes included changes to the NOx removal efficiency target, changes in the flue gas rate (load), changes to the NOx distribution profile, and changes to the level of process noise on the inlet NOx.

The results of the simulation studies show that:

- Average bulk-values do not accurately reflect variance in the SCR system, and in-turn do not accurately indicate system performance,
- Mal-distribution of inlet NOx, even at levels within design tolerances, significantly impacts NOx removal efficiency and ammonia slip,
- The significance of mal-distribution and limited instrumentation is more pronounced as NOx removal efficiency increases (confirmation of the non-linear nature of the first-principle relationships),
- Advanced control techniques can improve SCR performance, and
- The higher the level of variation in the inlet profile, the more benefit that can be derived from additional measurement and control instrumentation and advanced control techniques.

Future work will include investigation of the benefits of additional instrumentation and adjustable ammonia injection points.