Spray Flow Design for Once-through Circulating Fluidized Bed Boiler Control

Matias Hultgren*. Jenő Kovács. Enso Ikonen***

** Systems Engineering, University of Oulu, POB 4300, 90014 Oulu, Finland. firstname.lastname@oulu.fi*
*** Amec Foster Wheeler, Varkaus, Finland. jeno.kovacs@amecfw.com.*

Abstract: The present work examines the distribution of spray water in the superheating section for steam temperature control in a once-through circulating fluidized bed (OTU-CFB) boiler. Combustion power generation has become challenging due to increasingly fast load change demands. There is also a constant need to improve power plant efficiency, which leads to extreme operating conditions and complicated flowsheets. These factors emphasize the importance of advanced boiler control. The once-through steam cycle (OTU) has great potential for fast load changes, but due to a reduced steam storage capacity and a direct connection between the feedwater and the steam at the turbine, proper control design becomes even more crucial for OTU boilers. These challenges call for an interaction between control and process design. To achieve this, the authors currently investigate integrated control and process design for CFB boilers.

The steam temperature before the turbine is one of the major control targets in a steam power plant. The temperature is elevated stage-wise in the superheating section, which consists of several superheaters. The temperature is typically controlled between the individual heat exchangers with cooling desuperheater (attemperator) spray flows from the feedwater line. Due to the superheater time constants, as well as the possibility for local combustion side disturbances, both the steam temperature before the turbine and the intermediate temperatures after the superheaters should be controlled, especially for supercritical OTU boilers that operate close to material constraints. Selecting the spray flow distribution in the superheating line is also an important design issue, one for which clear guidelines are often not readily available.

The results of the investigation on the effects of the spray flow distribution on disturbance rejection and live steam properties are presented in this paper. The target system was a large-scale industrial OTU-CFB boiler, which utilized three desuperheater sprays (DSH). Additionally, the feedwater/saturated steam flows were investigated as inputs. The aim of the work was to formulate guidelines for selecting the spray flow distribution for steam temperature control. The objective was to find setpoint values for the individual DSH sprays in such a way that as large combustion side disturbances as possible could be rejected at each superheater stage without spray flow saturation. The controllability of the system was also first investigated using partial relative gain interaction analysis (PRG) as well as the frequency-dependent relative gain array. These initial results showed that the feedwater-spray flow system was integral controllable with integrity (ICI), and the control structure that was suggested by the PRG was also valid for higher frequencies.

A steady-state model was constructed to investigate the effects of the spray flow distribution on the superheating section. This first-principles model consisted of the heat balances of the superheaters and the desuperheater sprays, utilizing design parameters from a larger industrial simulator. Simple heat balances were also derived for combustion side units, and the overall model could be run either with constant heat fluxes or based on the temperature gradient between the combustion and water-steam sides. The results illustrated the spray water distribution tradeoff between disturbance rejection capability, the steam temperature profile and the generated steam megawatts. While the spray water gain on the steam temperature was larger close to the turbine, the steam temperatures lowered and the generated megawatts increased in the whole steam path, when more spray water was injected in the early superheating stages. Various spray flow distribution selection principles were tested in order to have set MW disturbance rejection margins at each stage. Different total spray water/saturated steam ratios were also simulated.

In the next stage of the work, the steady-state model was extended to a full Matlab/Simulink dynamic model to further examine the calculated spray flow distributions. This multi-stage transfer function model was based on the full heat balance differential equations for each heat exchanger, as well as a simpler storage model format for the steam flow. In future work, this model will be used for integrated control and process design by simultaneously altering process unit parameters, controller tunings and spray setpoints.

Keywords: CFB, power plant control, live steam temperature, desuperheater spray control, integrated control and process design.