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by Daniel Sommer, Piotr Olkowski, Dieter Rüsenberg and Heinz-Jürgen Wüllenweber

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Abstract

Optimising the firing system of a lignite-fired steam generator

Besides the 1,000 MW "BoA1" unit, the Niederaussem power plant comprises two 600 MW units and four 300 MW units generating electricity from Rhenish lignite.

In view of the changes to the situation in the electricity market and the anticipated future demands on these units, the steam generators have to meet new requirements. In addition, the firing systems must be adapted to cope with future coal qualities. For this reason, extensive work was undertaken on the entire plant during the inspection of unit G in 2011.

This paper reports on the structural conversion of the furnace of the 600 MW unit G and the subsequent adaptation and optimisation of the steam generator process. With the aim of optimising the steam generator's availability and flexibility, work started with the drawing up of a joint study by Steinmüller-Engineering and RECOM-Services. It was on the basis of these findings that the firing system in unit G was converted.

This report describes, compares and evaluates the initial situation, the concept of the conversion as well as the present situation following optimisation of fuel engineering..

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Introduction and description of the problem

As a domestic form of energy, lignite makes a significant contribution to electricity generation in Germany. Located between the cities of Cologne, Aachen and Düsseldorf, RWE Power operates lignite power plants on five sites with a total output of approximately 11,000 MW. Their operation requires around 85 million tons of lignite per year, which is used to generate electricity in the power plants. Besides the 1,000 MW „BoA1" unit, the Niederaussem power plant comprises two 600 MW units and four 300 MW units generating electricity from Rhenish lignite.

The electricity market has changed significantly as a result of increased usage of renewable energies. Lignite power plants, which were previously operated almost exclusively at base load, are being increasingly moved over to medium-load operation by load distributors due to the erratic nature of the supply from solar and, in particular, wind power. This means more frequent load changes and the lowest possible minimum unit loads. In light of current and more stringent future requirements regarding the flexibility of power plants and their minimum loads, comprehensive inspections were carried out and certain modifications deemed necessary.

Furnace-based optimisation was a key factor in these investigations in order to meet the changed boundary conditions of the electricity market in relation to steam generators. The furnaces also need to be adapted to handle future coal qualities. For this reason, extensive work was undertaken on the entire plant during the inspection of the 600 MW unit G in the first half of 2011.

This paper reports on the planning and structural conversion of the firing system in unit G at the Niederaussem power plant and the subsequent adaptation and optimisation of the steam generator process. With the aim of optimising the steam generator's availability and flexibility, work started with the drawing up of a joint study by companies Steinmüller-Engineering GmbH, based in Gummersbach, and RECOM-Services GmbH, based in Stuttgart. It was on the basis of these findings that the firing system in unit G was converted. This same measure was implemented in the second 600 MW unit H during the inspection in April 2012.

Concept determination

To optimise the furnace, a systematic examination of the entire current furnace system, including the burner and all associated burnout air, had to be performed. The inspected plant features a single pass steam generator with a steam output of 1,930 t/h (165 bar/530 °C HD). The tangential firing system consists of eight mills, seven of which are operated at full load. Adherence to the NOx limit value is ensured exclusively by means of furnace-based measures.

The plant was operated at full load with a total air excess of $\lambda = 1.35$. Due to the high proportion of burnout air in the overall air level, ignition was delayed in the burner belt area, resulting in poor utilisation of the furnace. This temperature distribution can be seen in Figure 1. This type of high-temperature operation also involved peaks of over 1,200 °C at the end of the combustion chamber and when exhaust gases were introduced into the convective heating surfaces. With some coals, this led to increased accumulation of coating and slag in the heating surfaces. Figure 2 shows an example of heavily soiled heating surfaces at the end of the combustion chamber.

These coatings on the pipes could only be partially removed using the existing steam blowers, meaning that the plant had to be taken out of operation for cleaning purposes after a relatively short period of time. The huge amount of effort involved in cleaning also resulted in long downtimes.

During low-load operation, the plant was limited by the fact that the NO_x emissions increased with a decreasing load and the limit value of 200 mg/m^3 under low partial loads could not be reliably met. This was due to the fact that the furnace combustion air supply had not previously been adapted to low-load operation. Furthermore, the high proportion of false and cooling air under partial load had a negative impact on the furnace.

Based on these findings, and with the aim of reducing the soiling tendency in the convective heating surfaces in order to increase availability and to achieve as low a partial load setpoint as possible while adhering to all boundary conditions, Steinmüller-Engineering GmbH and RECOM-Services GmbH drew up a joint study on furnace optimisation, which was used as the basis for converting and then optimising the pro-

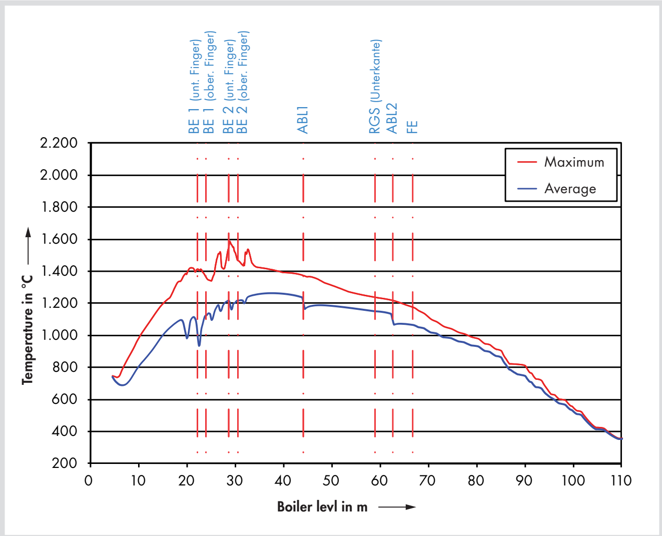

Fig. 1. Exhaust gas temperatures above the boiler level – before optimisation.

Fig. 2. Examples of heavily soiled heating surfaces at the end of the combustion chamber.

cesses and control systems of the plant during the inspection in the first half of 2011.

Within the scope of this study, the first step was to map the actual state of the steam generator using simulation calculations on the basis of measured operating data. These findings were then used to draw up design- and process-related recommendations and to assess these iteratively by means of further simulations. This procedure was used as the basis for finalising the conversion concept. The main burners and burnout air nozzles were then converted during the 2011 inspection based on these specifications. After re-commissioning, the control system of the combustion air supply at the main burners and at the burnout air levels was adapted.

To assess the new actual state, new simulation calculations were performed under full and partial load as part of a boiler measurement and on the basis of recorded operating data. The results were compared with the simulation results prior to furnace optimisation. Visual inspections were also performed, drawing on users' operating experience, to assess the soiling behaviour of the steam generator following the conversion of the furnace. The water-steam circuit and control system were also extensively optimised based on the changes made to the furnace. These are not, however, described in further detail in this paper.

Burner conversion: optimisation of the furnace with two burnout air levels

The eight main burners of the tangential firing system are divided into two levels: the upper and lower burner levels. Each burner level features two coal dust fingers with core air pipes arranged in a cross formation in the coal dust fingers. The main proportion of combustion air was supplied to each burner level via lower, middle and upper air nozzles. Figure 3 shows the burner array on one level before the conversion. On average, only small speed fluctuations were noticeable on the dust and combustion air sides. The reason for this unfavourable speed ratio is that following the last optimisation of the furnace with the objective of low-NO_x operation, no further adaptations were made to match the changed coal quality.

By optimising the burners, higher air speeds should be reached at lower dust speeds, with a lower height of the burner array. The existing burner bucklings in the combustion chamber walls were left unchanged. Figure 4 shows the new burner array and the new burner setup. The secondary air cross-sections were designed in such a way that a speed of > 45 m/s can be achieved under full load. The coal dust is introduced into the furnace at a speed of 15 m/s. The high relative speed between the exhaust gas and the combustion air results in improved mixing and therefore a faster burnout. Each pair of coal dust fingers is separated by horizontal core air pipes alone. The vertical core air pipes are no longer required since the entire burner is made from heat-resistant steel (Sicro 23/20).

Both burnout air levels were subjected to various air volumes and therefore various air speeds. During the course of optimisation, air speeds were to be increased and air volumes reduced. To this end, the number of burnout air nozzles on the two burnout air levels was reduced by half and the geometry of the nozzles modified. Figure 5 shows the new nozzle arrangement on the two burnout air levels along with the associated air discharge speeds. Here, half of the original 16 nozzles on each level have been closed. The geometry of the remaining eight nozzles has been optimised and the nozzles subjected to corresponding air speeds.

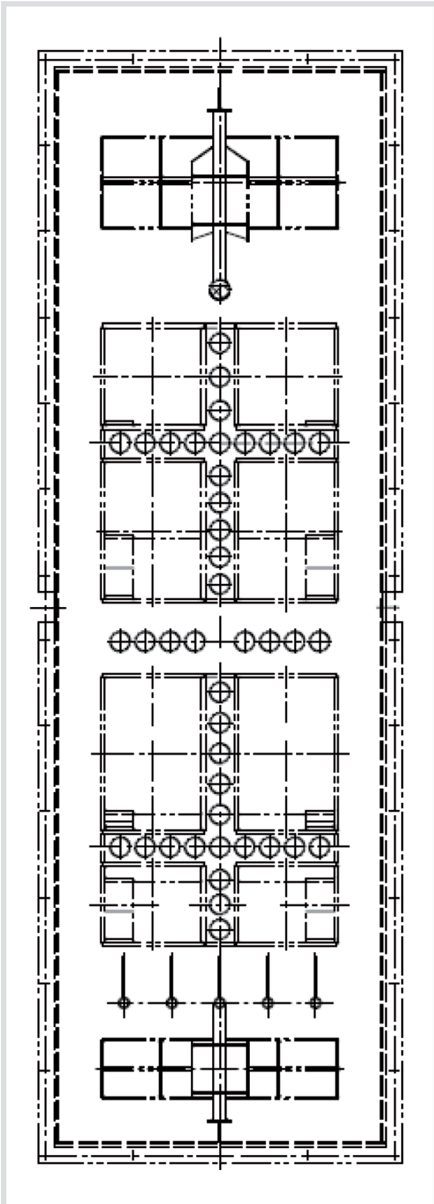

Fig. 3. View of the burner array on one level before the conversion.

Before the conversion, extensive simulations were worked out and optimised for the modifications to be made. Both the furnace-based optimisation and the plant-based measures were key to the assessment.

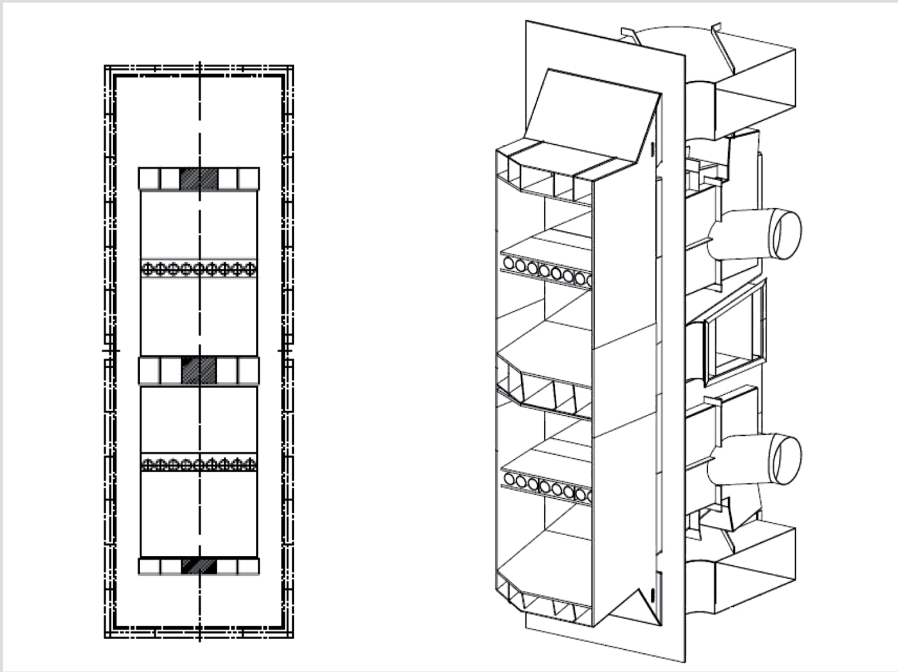

Fig. 4. The new burner array and the new burner setup.

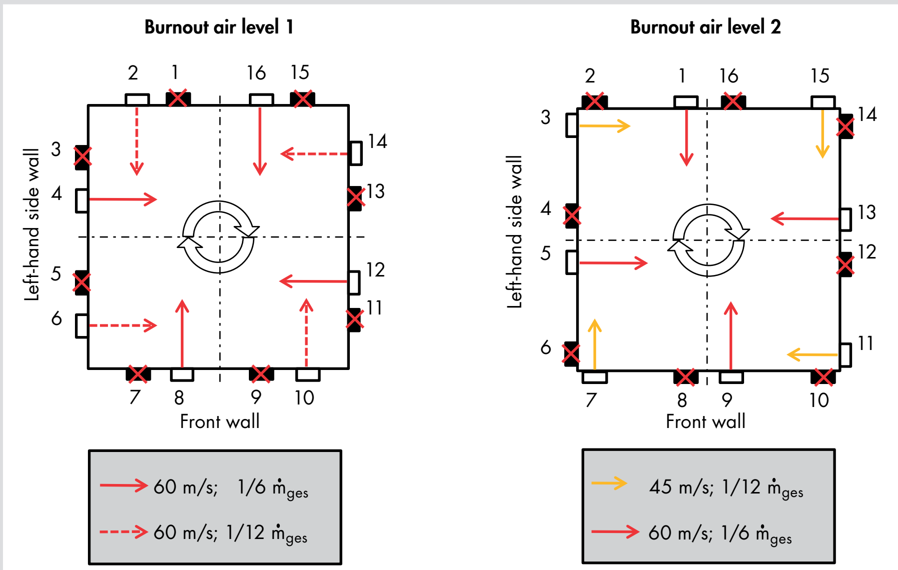

Fig. 5. The new nozzle arrangement on the two burnout air levels along with the corresponding air discharge speeds.

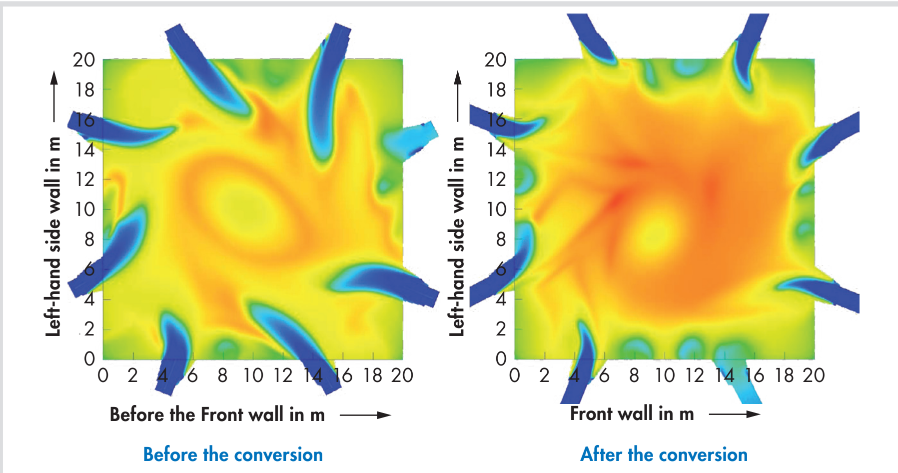

Fig. 6. Temperature distribution cross-section near to the upper dust finger in the lower burner level.

Comparison of the simulation calculations before and after the conversion

One important aim of the furnace-based optimisation was to achieve early ignition in the burner zone, thus ensuring the greatest possible fuel conversion within the burner zone. Following the conversion, which took place during the 2011 inspection, and after re-commissioning, a new simulation calculation was performed based on operating data. The results of these simulations based on real operating data before and after the furnace was optimised are compared and evaluated below. Figure 6 shows the temperature distribution cross-section near to the upper dust finger in the lower burner level. In the image taken after the conversion, considerably higher temperatures can be seen in the burner zone, which indicate a more intensive mixture of fuel and air and, in turn, greater fuel conversion within the burner zone.

This trend is also confirmed by comparing the axial temperature profiles above the boiler level. Figure 7 shows the temperature isosurface of 1,200 °C in grey. It is clear to see that this temperature isosurface reaches far into the convective heating surfaces in the original construction. Following the conversion, this temperature isosurface ends below the heating surfaces. Figure 8 shows the temperature distribution cross-section at the end of the combustion chamber immediately before entry into the convective heating surfaces. Following the conversion, a significant drop in the high temperatures at the end of the combustion chamber can be seen. This is a result of the fast fuel conversion in the burner belt.

A further factor in fuel conversion is the CO content. Figure 9 shows the CO concentration cross-section at the burner level. A significant drop in the CO concentration following the conversion can be seen here.

The increased temperature in the burner belt (Figure 6), the drop in the high temperatures at the end of the combustion chamber (Figures 7 and 8) and the simultaneous drop in the CO concentration in the burner belt (Figure 9) clearly confirm that the burner conversion has resulted in early ignition and considerably improved fuel conversion in the lower area of the combustion chamber.

Figure 10 shows the isosurfaces of 0.5 Vol.% CO around the two burnout air levels before and after the furnace optimisation (colour: magenta). Here too it is clear that the optimised burnout air volumes and speeds have resulted in an improved mixture of the combustion air with considerably more effective residual combustion. This is reflected in the lower CO content in both burnout air levels.

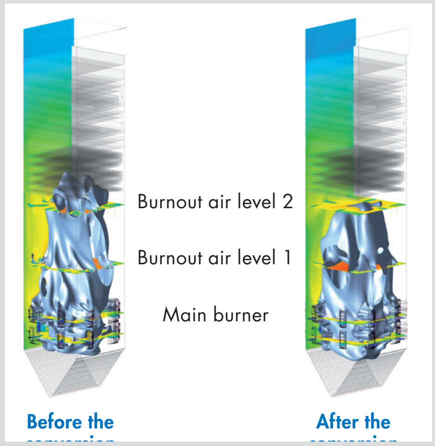

Fig. 7. Temperature isosurface of 1,200 °C.

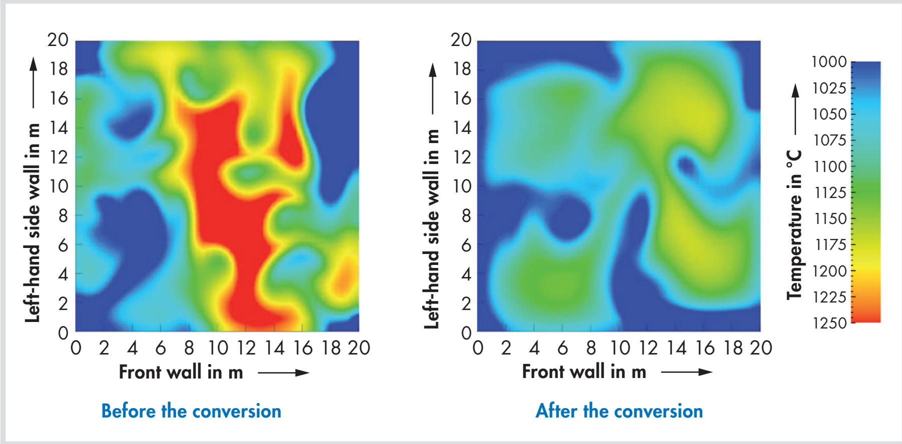

Fig. 8. Temperature distribution cross-section at the end of the combustion chamber immediately before entry into the convective heating surfaces.

Operating experiences after the conversion

Operating experiences at unit G since recommissioning after the 2011 inspection have shown that optimisation has had a positive effect on the furnace. The soiling tendency has improved considerably in the heating surfaces. This is partially due to the lower drop in effectiveness of the heating surfaces and subsequent increase in the time between steam generator overhauls and partially due to the decreased hardness of the caking.

In light of this, the time required for thermal- or safety-related cleaning could be reduced significantly. The partial load capacity of the plant has also been improved in terms of the load ramps and reduced load. The reduction in total air volume has improved the efficiency of the steam generator.

On the basis of these significant improvements, the optimisation measures described above were also implemented on the virtually identical 600 MW unit H during the 2012 inspection. Operating experiences to date show that improvements have been made here too.

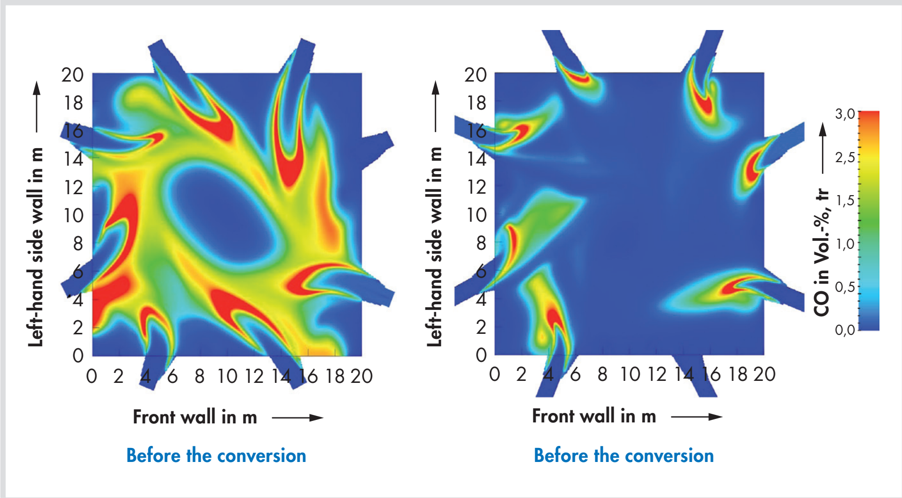

Fig. 9. CO concentration cross-section at the burner level.

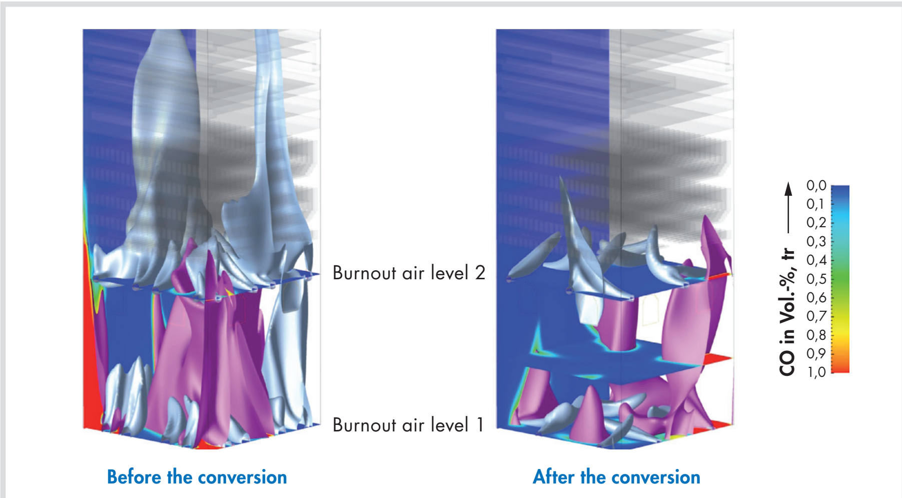

Fig. 10. Isosurfaces of 0.5 Vol.% CO around the two burnout air levels before and after the furnace optimisation (colour: magenta)