

## **Modernisation of a lignite-fired steam generator – Reduction of NO<sub>x</sub> emissions**

By Ralf Kriegeskotte, Quinto Di Ferdinando,  
Hans-Ulrich Thierbach and Bernhard Zimmermann



# Modernisation of a lignite-fired steam generator – Reduction of NO<sub>x</sub> emissions

Ralf Kriegeskotte, Quinto Di Ferdinando, Hans-Ulrich Thierbach and Bernhard Zimmermann

## Kurzfassung

### Modernisierung eines braunkohle-gefeuerten Dampferzeugers – Reduzierung der NO<sub>x</sub>-Emissionen

ContourGlobal Maritsa East 3 ist ein mit Braunkohle befeuertes Kraftwerk mit einer installierten elektrischen Leistung von 4 x 227 MW<sub>el</sub>. Die 4 Dampferzeuger russischer Bauart mit einer Dampfleistung bis 730 t/h wurden in den Jahren 1978 bis 1981 in Betrieb genommen.

Um den Betrieb des Kraftwerks langfristig sicherzustellen, müssen die NO<sub>x</sub>-Emissionswerte von bis zu 400 mg/Nm<sup>3</sup> sicher unter den künftigen gesetzlichen Grenzwert von 200 mg/Nm<sup>3</sup> (jeweils bezogen auf 6 % O<sub>2</sub>, trocken) bis Ende 2015 reduziert werden (EU-Richtlinie 2010/75/EU für Industrieemissionen).

Das Konsortium Steinmüller Engineering GmbH, Gummersbach und Siemens EOOD, Sofia, beide Firmen gehörend zum Siemens Konzern, hat im Auftrag des Kraftwerkseigentümers und -betreibers, ContourGlobal Maritsa East 3 AD, Sofia, den erfolgreichen Umbau der Feuerung der Kesselanlage 4 dieses Kraftwerkes durchgeführt.

Wesentliche Herausforderungen stellten die sehr kompakte Kesselgeometrie mit vergleichsweise kurzen Verweilzeiten und die Qualität der bulgarischen Braunkohle dar. Charakteristisch für die Kohle sind ein Heizwert von 6 bis 7 MJ/kg, ein Wassergehalt von 50 bis 60 %, ein Aschegehalt im Bereich von 10 bis 20 % sowie ein sehr kritisches Verschlackungsverhalten.

Steinmüller Engineering entwickelte und realisierte ein Modernisierungskonzept, welches als Resultat eine umfassende Lösung für die technisch komplexe und außerdem terminlich extrem anspruchsvolle Aufgabenstellung des Kraftwerksbetreibers liefert. Nach dem Umbau steht diesem ein Kraftwerksblock zur Verfügung, der umweltfreundlicher, zuverlässiger und zudem effizienter und somit wirtschaftlicher die lokale Braunkohle verstromt.

## Introduction and description of task

### Situation prior to revamping the firing system

ContourGlobal Maritsa East 3 thermal power plant with a capacity of 4 x 227 MW<sub>el</sub> is one of the largest power plants in Bulgaria. It is located next to the coal mines of Maritsa East, in the South East of the city of Stara Zagora and close to the town of Galabovo. These coal mines provide the power plant with lignite, which has very high moisture, sulphur and ash content and a comparatively low calorific value (Table 1). At the same time, this lignite tends to a critical slagging behaviour in the furnace, which had to be considered thoroughly during project execution.

The 4 steam generators were built by the Podolsk Boiler Works in Russia and commissioned between the years 1978 and 1981. After privatisation of the power plant at the beginning of this century, a substantial rehabilitation took place between 2003 and 2009, which allows coping with all currently existing environmental requirements.

With respect to the further environmental requirements for the power plant to reduce NO<sub>x</sub> emissions below 200 mg/Nm<sup>3</sup> (at 6 % O<sub>2</sub>, dry gas), ContourGlobal decided to have the existing firing system again revamped extensively in order to meet those requirements by primary measures.

### Technical objectives for the project

The technical requirements and objectives for this project can be summarised as follows:

- Reduction of the NO<sub>x</sub> emissions from approximately 400 mg/Nm<sup>3</sup> to below 180 mg/Nm<sup>3</sup> at 6 % O<sub>2</sub>, dry gas,
- Efficiency increase of the furnace by reduction of the excess air ratio from 1.2 to 1.15 (at furnace outlet),
- Keeping the CO emissions below 180 mg/Nm<sup>3</sup> at 6 % O<sub>2</sub>, dry gas,
- Preventing the water walls from corrosion,
- Preventing the furnace from slagging, and
- Keeping the parameters of the pressure part in the range as before revamping.

## Project execution

### Determination of the concept

To achieve the above-mentioned goals and contractual obligations, a new concept for the entire firing system had to be developed:

### Modification of the main burners

With the existing configuration of the coal dust burners, it was not possible to achieve the reduction of the NO<sub>x</sub> formation to the required emission levels. Therefore, a new design for the burners was developed and optimised based upon a similar design with good experiences of successfully executed projects in other utilities. A good blending of the air in the gas/coal dust flow requires a relative high difference in speed between both flows. In this respect, the cross-sections of the secondary air at the main burner (upper, core, intermediate and lower air flow) and of the dust fingers were adjusted taking into consideration the adapted air flow to the burners. For stable firing of the coal dust/air mixture in

## Authors

### Ralf Kriegeskotte

Steinmüller Engineering GmbH  
Gummersbach/Germany

### Quinto Di Ferdinando

ContourGlobal Maritsa East 3 AD  
Sofia/Bulgaria

### Dr. Hans-Ulrich Thierbach

Dr. Bernhard Zimmermann  
Steinmüller Engineering GmbH  
Gummersbach/Germany

Tab. 1. Typical analysis for Maritsa lignite.

	As received	Dry-ash-free
C [%]	20.35	67.83
H [%]	1.70	5.67
O [%]	6.26	20.87
N [%]	0.36	1.20
S [%]	1.33	4.43
Water [%]	53.00	–
Ash [%]	16.97	–
Net calorific value [MJ/kg]	6.425	25.706

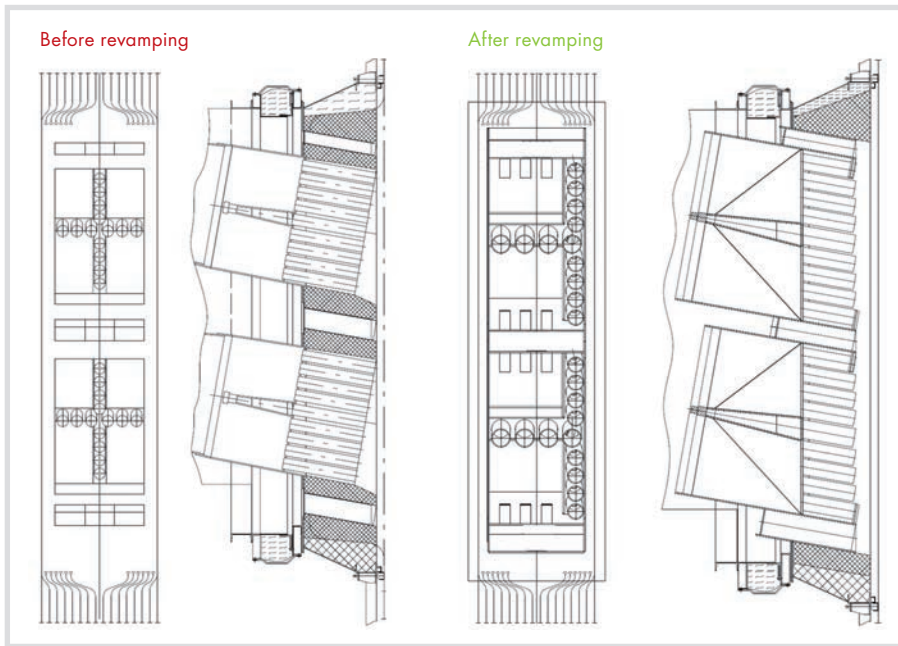


Fig. 1. Comparison between the old and the new burner design.

the proximity of the burner outlet, flame stabilisers are used at the exits of the individual coal dust fingers. The stabilisers serve to slow down part of the dust particles and thus to create a turbulence of particles, to speed up the release of volatiles and to stabilise the ignition close to the outlet of the burners.

The arrangement and size of the core air pipes for the main burners are designed to ensure a proper mixing of pulverised fuel with the combustion air and to provide an integrated system of protection air of the furnace water wall. Hence this design will significantly decrease the slagging and corrosion risk in the burner belt area. In Figure 1 the old burner and the revamped burner design are compared.

**Installation of a new side wall and over-fire air system**

In order to protect the membrane walls against corrosion and slagging and to support air staging in the furnace for efficient NO<sub>x</sub> reduction, a new side-wall-air system (SWA) located at each wall of the boiler was installed. Each wall was equipped with SWA nozzles, which create the necessary O<sub>2</sub> atmosphere at the furnace walls.

Also a new over-fire-air system located at the front and rear wall of the boiler was installed in order to inject the required remaining air amount necessary for complete combustion of the reaction products above the top burner level at a fixed distance and high velocity. The strong impulse of this air injection creates a good penetration and mixing of the flue gas with the air and pro-

vides the required oxygen for the combustion of the carbon monoxide that is not yet completely converted in the burner area.

The new combustion design provides an optimised residence time for the coal particles in the combustion chamber by reducing the height of the primary burner belt zone and increasing the height of the secondary zone above the top burner level (burnout stage). This is achieved by staging the primary combustion along the vertical axis of the furnace in front of the lower burner part. This staging has a significantly positive effect on the NO<sub>x</sub> formation, because the oxygen concentration and the formation of fuel NO<sub>x</sub> are closely interconnected.

**Pulverised fuel (PF) system**

Figure 2 shows another area of the firing system, where optimisations have been realised. The respective measures were conducted at the pulverised fuel ducts targeting for an optimised pulverised fuel and vapor distribution for the new low-NO<sub>x</sub> firing system.

In order to find the optimal solution regarding the modifications both a 3D CFD model and a physical model have been realised during the short engineering phase. To validate the results of the CFD-model, tests were performed in the physical flow model (scale: 1:10). The model is shown in Figure 3.

The results of the CFD model were in very good accordance with the physical flow model (Figure 4), which gave additional safeness for the further project execution. Also the later distribution measurements on site, executed during tests in the hot commissioning stage, were in good compliance with the model results.

With this arrangement it was possible to find the best suitable coal/vapour distribution by varying the respective settings. Due

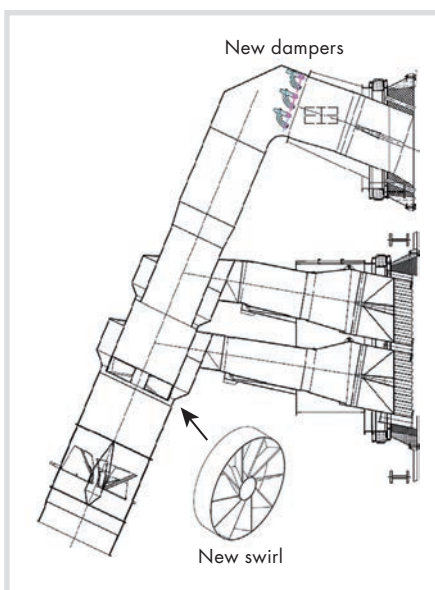


Fig. 2. New PF concentrator and vapour dampers.

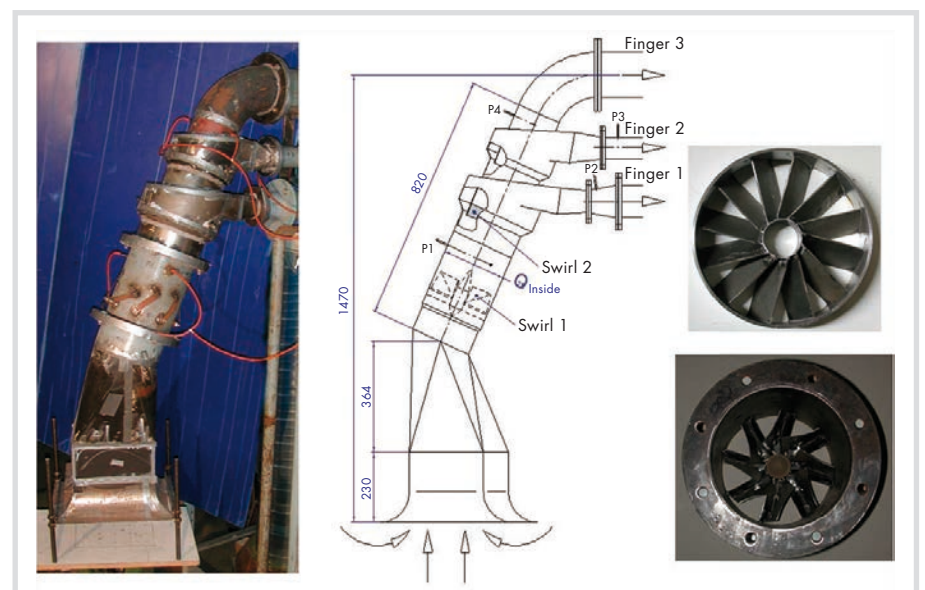


Fig. 3. Physical model.



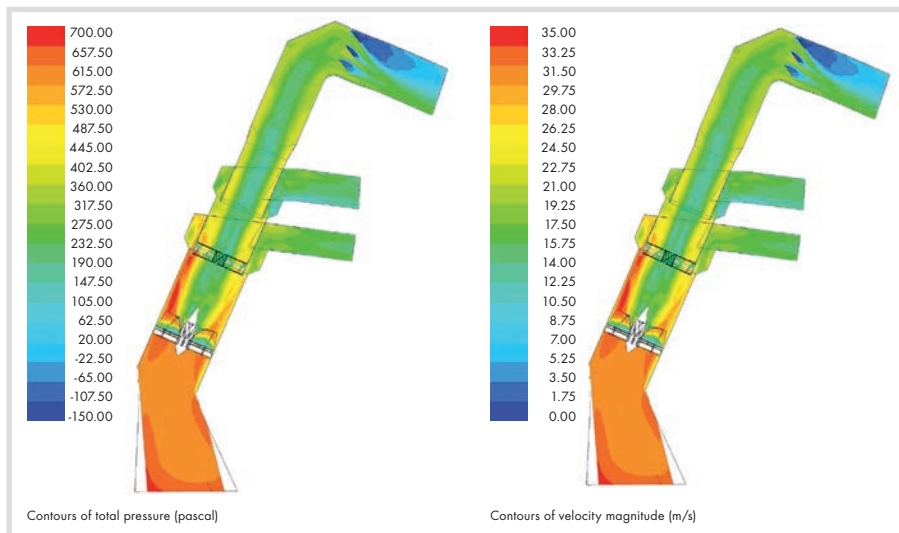


Fig. 4. CFD results for the new PF concentrator and the vapour dampers.

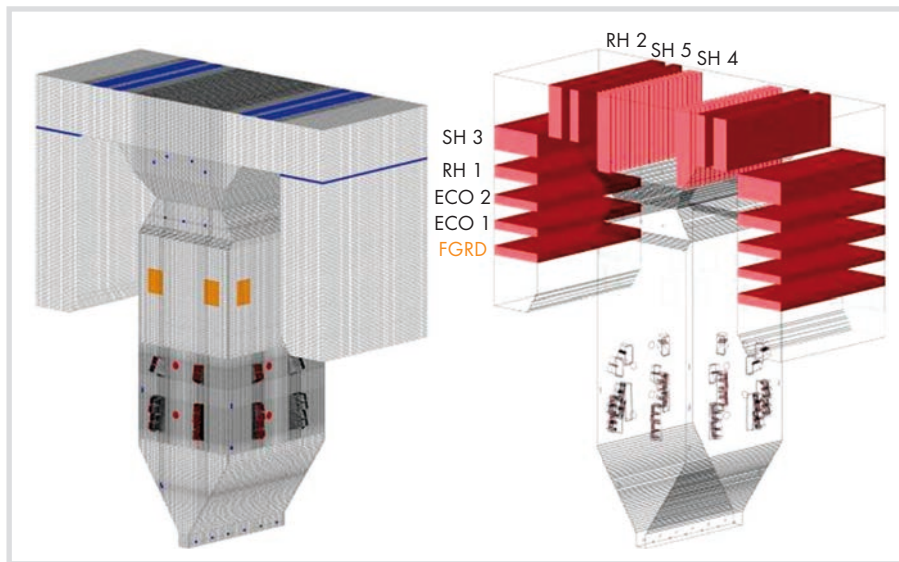


Fig. 5. Model of the combustion chamber and the boiler.

to the new installation, the required distribution of pulverised fuel and gas could be adjusted during commissioning of the new firing system. Depending on the fired coal, the PF and gas distribution can also be varied later, if needed.

**CFD simulation of the furnace chamber**

All optimisation steps for the firing system with an influence on the furnace, starting with the over-fire-air and the side wall air nozzles and ending with the new main burners were validated in a special 3D-combustion model. This model is representing state-of-the-art software and being tailored for the modelling of industrial furnaces and boilers in cooperation with Recom. The 3D-furnace model of Unit 4 in ContourGlobal Maritsa East 3 consists of 11 million cells in which, depending on the boiler load, 50 to 100 equations were solved each. For converged CFD results 30,000 to 60,000 iterations had to be performed. The combustion chamber model is shown in Figure 5.

The CFD results before and after the re-ramping measures for Maritsa East 3 are in good accordance with reality, especially with respect to the measured NO<sub>x</sub> values.

**Milestone time schedule**

The consortium was entrusted with the contract for the project execution of unit 4 mid-April 2012. The most challenging issues with respect to the schedule were, having all equipment been ready designed and manufactured for the contractual outage period which started only 5 months after the contract award and to have the unit back in operation at the agreed point in time.

This extreme short schedule lead to various overlapping activities during the project execution and requested very short communication channels and response times from all partners involved.

In order to meet a further requirement of having the synchronisation even two weeks earlier than originally scheduled, a solution had to be found, how to reach this objective, without the entire completion of the over-fire air system, as this was impossible to be realised at that point in time. Thus, it was decided between the parties to install temporarily additional blind flanges and start commissioning without over-fire air system. This solution worked very properly and the unit could be operated in the full load range at the requested earlier date, as shown in Table 2.

During a very short downtime in December 2012 the new over-fire air duct system then was connected to the new over-fire air nozzles and to the existing secondary air system of the unit. Thereafter a very intense optimisation of the new firing system was conducted with almost 30 different test

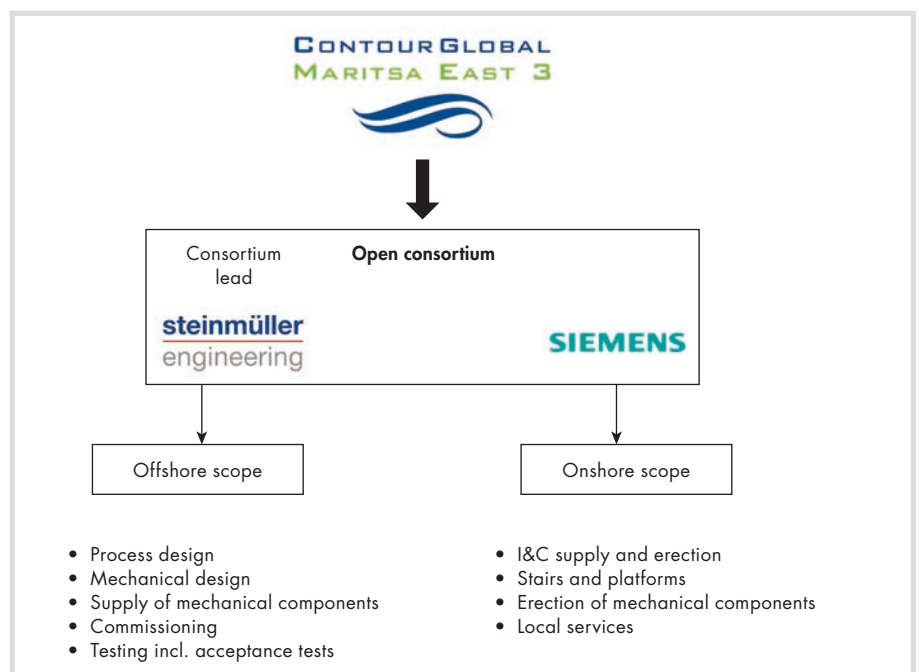


Fig. 6. Project set-up.

Tab. 2. Contractual and actual project milestones.

Milestone	Contractual date	Actual date
Contract award	2012-04-18	2012-04-18
Start of outage	2012-09-20	2012-09-16
End of outage – Synchronisation	2012-11-29	2012-11-16 (OFA duct system completion later)

Tab. 3. Operational results after revamping and optimisation of the firing system.

Parameter	Unit	Before revamping	After revamping target	After revamping actual
NO <sub>x</sub>	mg/m <sup>3</sup> *	350 to 400	< 180	150 to 180
CO	mg/m <sup>3</sup> *	< 60	< 180	30 to 80
Excess air ratio (furnace exit)	[-]	1.2	1.15	1.1
Boiler efficiency	[%]	~ 83.5	–	~ 83.5 + 1.0
Percentage of furnace wall area with O <sub>2</sub> content < 0,5 %	[%]	–	30	< 5

\*s.t.p. 6 % O<sub>2</sub>, dry gas

settings having been checked in order to find the best suitable settings and to meet all targets as described above at the same time.

### Project set-up

The project set-up selected for this project is an open consortium, in which Steinmüller Engineering is responsible for the consortium lead and for the so called “offshore scope”, whereas the local consortium partner Siemens EOOD took over the responsi-

bility for the so called “onshore scope”. The responsibilities as a result of this set-up are illustrated in Figure 6.

### Operational experiences after revamping the unit

For the hot commissioning of the first unit a very extensive and detailed optimisation and testing programme was worked out in order to find the best combination of possible settings. In order to realise this test programme completely also the require-

ments and restrictions of the power plant and the grid operator had to be taken into account.

The various setting modifications finally lead to an optimal combination of settings, which then was the basis for the execution of the performance tests and the following 120 h acceptance tests, which were successfully conducted. The contractually guaranteed parameters could all be met or even outstripped, which is shown by summarizing of operational results in Table 3.

### Perspective

The technical and timing project results as described above are extremely satisfying for the owner as well as for the consortium. Despite the time constraints and the very high technical requirements for this project, all relevant objectives were met. Thus, based on the results achieved ContourGlobal entrusted the consortium with revamping the firing system of the next unit (Unit 3) of the power plant in January 2013. This project is now in the execution phase and supposed to be finished within 2013. Units 2 and 1 will then be revamped in the following two years in order to have the entire power plant ready for the new NO<sub>x</sub> limits required by Directive 2010/75/EU on Industrial Emissions before 2016.