Meeting the operational challenge of maintaining security of supply

Power engineers are seeking to reconcile the seemingly contradictory demands of delivering increased performance with minimal investment, and yet still meet their emissions targets. John Goldring reports.

Los ingenieros energéticos intentan conciliar las demandas aparentemente contradictorias de ofertar un mayor rendimiento con una inversión mínima, y a la vez cumplir con sus objetivos de emisiones. John Goldring informa.

Energieversorgungs-techniker sind darum bemüht, die offensichtlich widersprüchlichen Forderungen nach Leistungssteigerungen mit minimalen Investitionen und zugleich das Erreichen der jeweils gesteckten Emissionsziele miteinander in Einklang zu bringen. Ein Bericht von John Goldring.

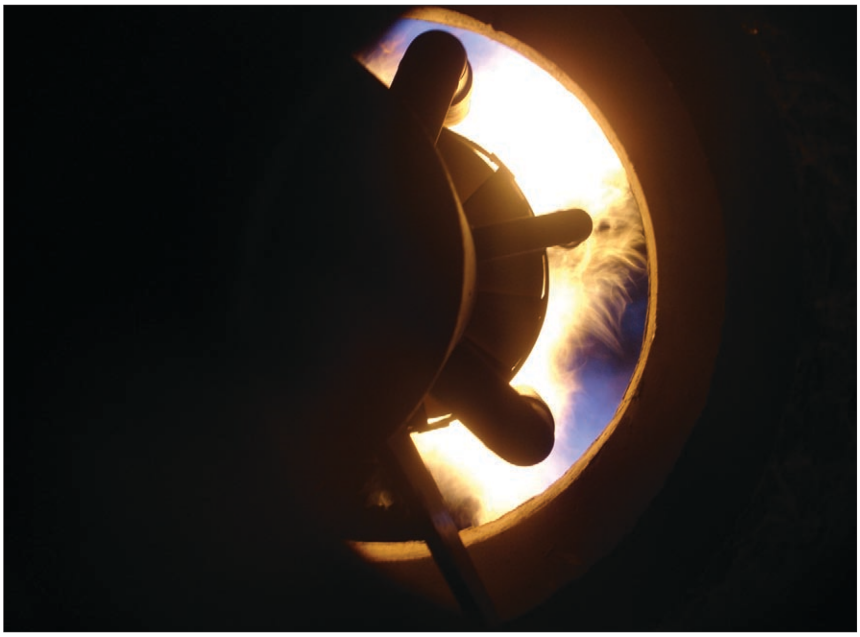

Fig. 1. Many plants where operational flexibility has been increased by modifying the combustion systems so that they can run on more than one fuel type.

Wherever they are in the world, power engineers at electricity generation stations and large combustion plant are facing similar challenges. Security of supply issues, impacting on a plant's preferred input fuel has meant that plants are having to be much more flexible in terms of what their input fuel is. For example, it is not unusual for coal-firing plant to source coal from a number of different countries, depending on current/future price and availability.

Needless to say, different coals have different combustion characteristics, so being able to change coal type and maintain operational effectiveness is an important part of a power engineer's remit.

Similarly, there are many plants where operational flexibility has been increased by modifying the combustion systems so that they can run on more than one fuel type. Switching between say coal and oil takes that operational challenge a stage further for power engineers, who must be able to manage a smooth change-over with minimal reduction in output.

Set against this background of a requirement for increased operational flexibility in terms of input fuels, the regulatory environment has been going in the other direction, with legislation governing emissions becoming ever tighter.

And as if that was not enough, the changing landscape of the energy sector, in terms of increased liberalisation and new, market-driven ownership structures, has meant that the focus on financial performance has never been greater. Shareholders have been demanding bigger profits and have often been reluctant to commit significant levels of additional investment to what is already a capital-intensive industry.

This is known as 'sweating the assets' but it is the power engineers that have ended up sweating as they seek to reconcile these seemingly contradictory demands placed upon them of delivering increased performance, with minimal investment and yet still meeting their emissions targets.

For the reasons explained above, RJM is fully aware that wholesale replacement of existing equipment is often not an option and has built a reputation for itself as a company that can achieve full emissions compliance without having to resort to major component replacement.

Instead, through a combination of complex monitoring of every critical stage of the combustion process and Computational Fluid Dynamic (CFD) analysis, RJM is able to identify and make sufficient changes – in just a handful of key areas – to ensure not just compliance, but often compliance at a level well below current regulations.

RJM has recently applied its experience and CFD modelling know-how to determine the most suitable technologies to achieve NOx reduction at three sites in Europe; AES Tisza II in Hungary, Mersin Soda in Turkey and AES Kilroot in Northern Ireland.

Significantly, two of these projects included the upgrade of existing low NOx systems. This showed it was possible to make improvements to allow ongoing compliance with the EU's Large Combustion Plant Directive (LCPD), at minimal cost and downtime.

AES Tisza II, Hungary

AES Tisza II, located 200km east of Budapest, is a 900MWe gas and oil power plant. Commissioned in 1978, the plant was subject to various upgrades over the years, but by the time Hungary joined the EU in 2004, plant managers were faced with having to implement a step change in emissions performance to meet the more stringent requirements of the LCPD. These included reducing its NOx levels by two thirds when firing gas and by more than one half when firing on oil.

The company was aware of RJM International's strong track record in the US where it had achieved NOx emissions reductions on over 50 000MWe of installed plant and appointed the company to help it reach the new NOx targets.

Once on site, RJM engineers measured the existing furnace and burner geometries and then entered the data into the baseline CFD model. This model was then run (ie virtual data matching actual data) until convergence was achieved. The data was then analysed in terms of fluid flow and emissions, paying particular attention to thermal behaviour, NOx profiles and CO profiles.

From the baseline NOx contours, as predicted by the CFD analysis, and it was clear that that the convergent effect of the flames has a detrimental effect on the emissions profile of the furnace. Since there is a large region of high peak flame temperature, the majority of the NOx is produced close to the burners.

The predicted NOx contours for the upgrade were be contrasted with the baseline. The high NOx region was significantly reduced, mainly because of the reduction in peak flame temperature.

The temperature contours in the vertical plane of the furnace (through the burner centre line) were compared with the baseline. Peak flame temperatures are reduced from 1927°C in the baseline to 1816°C in the upgrade and that the region of peak flame temperature is significantly more diffuse resulting in improved heat transfer in the furnace and then through the convective heat exchangers in the boiler.

Once the CFD analysis had confirmed what burner upgrades were required, RJM set about designing

Results Summary Table

Site	AES Tisza II (Hungary)	Mersin Soda (Turkey)	AES Kilroot (Northern Ireland)
Boilermaker	Deutsche Babcock	Schelde, Gama, Fives-Caille	NEI
Original Burnermaker	Deutsche Babcock & Alstom	Hamworthy DFL, B&W, Pillard	Alstom LNCFS II
Boiler Load and No.	4 x 225MWe	1 x 200t/hr, 2 x 100t/hr	2 x 260MWe
Firing Configuration	Upshot (burners in the floor)	Front Wall	Tangential
Fuels Fired	Oil, Natural Gas, Inert Gas	Oil, Natural Gas	Coal, Oil
Scope	Burner Modifications, FGR	Burner Modifications	Burner Modifications. OFA Modifications, Dynamic Mill Classifiers
Original NOx (Gas)	1100 mg/m_0^3	Gas Conversion Project	–
Upgrade NOx (Gas)	140 mg/m_0^3	180 mg/m_0^3	–
Original NOx (Oil)	850 mg/m_0^3	>500 mg/m_0^3	491 mg/m_0^3
Upgrade NOx (Oil)	170 mg/m_0^3	380 mg/m_0^3	383 mg/m_0^3
Original NOx (Coal)	–	–	648 mg/m_0^3 (South African fuel)
Upgrade NOx (Coal)	–	–	420 mg/m_0^3 (South African fuel)
Other Benefits of the Project	Improved boiler efficiency.	Improved boiler efficiency, elimination of flame impingement, elimination of furnace vibration	Significnt reduction in Carbon in Ash level

and commissioning the fabrication of new low NOx gas burner assemblies, low NOx stabilisers and low NOx oil atomisers. These components were manufactured for RJM by specialist fabricators in the UK.

Following the RJM upgrade, NOx reductions of 80 per cent firing gas and 72 per cent firing oil were achieved. Boiler efficiency at full load under performance test conditions also increased by 1.1 per cent (from 93.8 per cent to 94.9 per cent) resulting in major savings in fuel and boiler running costs.

Mersin Soda, Turkey

Mersin Soda is an industrial plant manufacturing chemicals for the glass industry and is located 100 miles south west of Adana on the Mediterranean. The scope of this project was to upgrade the burners on all three boilers to offer the plant operators the option of natural gas-firing, while maintaining the original oil-firing capability.

On one of the boilers, a Schelde unit fitted with Hamworthy low NOx burners, the client had concerns about introducing a new fuel type because even though the oil atomisers had been modified in the lower rows to keep the flames away from the floor, it had suffered from flame impingement and boiler vibration ever since it was first commissioned.

To resolve this, RJM employed CFD modelling to replicate the existing system and to determine what changes would be needed to solve the flame impingement issue. A figure of 5000ppm iso-surfaces of carbon monoxide (CO) was shown when firing oil; this means the CO concentration inside the red plume is greater than 5000ppm and everything outside has a lower CO concentration.

The CO shows where the combustion is taking place and the baseline, showed what was actually happening on site with the bottom burners hitting the floor at some point between the mid furnace and the rear wall.

The upgrade predicted the problem would be solved with the RJM design. In assessing the problem, RJM's combustion and CFD engineers could see from the model that the swirl direction of the existing burners was pulling the fires onto the floor. To solve this, RJM imposed new counter-rotating swirl directions to the burners.

Following installation, combustion was optimised by balancing air and fuel flows and RJM's optimisation process resulted in a final boiler excess O_2 of <2 per cent from a starting point of >4.5 per cent, thereby improving boiler efficiency. Flame impingement and furnace vibration were eliminated.

The RJM burners on all boilers met all performance guarantees for both oil and gas firing NOx was reduced to 180mg/m_0^3 @3 per cent O_2 on gas and 380mg/m_0^3 @3 per cent O_2 for oil.

AES Kilroot, Northern Ireland

AES Kilroot power station is a 520MWe plant, located at Carrickfergus, North East of Belfast. There are two 260MWe coal and oil-fired NEI boilers. The boilers are tangential-fired, fitted with a Low NOx Concentric Firing System (LNCFS II). Current NOx emissions were 648mg/m_0^3 on coal and 491mg/m_0^3 on oil. RJM's target was to achieve <500mg/m_0^3 on coal, and <400mg/m_0^3 on oil.

To achieve this, RJM installed burner modifications, Overfire Air (OFA) modifications and coal mill classifier upgrades. Critically, the upgrade had to be achieved without adversely impacting on Carbon-in-Ash (CiA) levels, whilst still achieving the desired reduction in NOx.

To address this combined NOx/CiA challenge, RJM developed a visual diagnostics method that provided excellent results and diagnostic insights into the char reaction process.

The diagnostics showed coal particle trajectories coloured by carbon concentration. The single nozzle injection shown started off with maximum carbon concentration (red), and as the carbon was oxidised, the paths become more blue, with dark blue being nearly 0 per cent carbon. This type of diagnostic not only showed where the coal is going in the furnace, but where it is being oxidised.

Carbon concentration could also be shown as a filled contour. This allowed for identification of high 'C', concentrations during OFA optimisation. This type of view shows how the coal particles actually interact with supplied air though either the offset or OFA ports.

CFD analysis

A systematic optimisation path was also used at Kilroot and the table below summarises the key results. The table below gives the CiA from the baseline case as a function of injection port. It was found that 52 per cent of the CIA came from a lower mill. By increasing the amount of air to the lower furnace, the CFD model showed CiA was reduced.

Case	**CiA**	**NOx Reduction**
Base	6.45%	–
Modify coal injections	16.9%	25%
OFA optimisation	**4.65%**	**33%**

Several OFA iterations were accomplished until an optimal configuration was determined predicting a 33 per cent NOx reduction, with a good reduction in CiA.

CFD modelling predicted that emissions guarantees would be met and provided a valuable insight into how the combustion system should be optimised to control both NOx and CIA. ❍

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