Small changes, big effects

Big emission cuts for fossil fuel plants achieved using relatively simple efficiency tweaks, says **John Goldring**

THESE days, if you pick up a newspaper, listen to the radio or watch TV you're never that far from an energy story and usually it's all about climate change, carbon emissions and the latest innovation in renewables.

But the reality is that even though renewables gets all the attention, most countries still rely on fossil fuels and/or nuclear for the bulk of their base-load generation. What's more, this reliance on non-renewables is a situation that is set to prevail for decades to come, despite the fact that most governments are now committed to migrating towards low- or even zero-carbon power generation technologies.

Typically, fossil fuel means coal-, oil- or gas-fired LNG (liquified natural gas) plants and while the latter have the lowest emissions, they are not the predominant generator type, as CCGT (combined cycle gas turbine) plants are a relatively recent innovation.

So the reality in most developed countries (as well as China and India) is that the generation portfolio still features a large number of coal- and oil-fired plants. At many stations, the oldest parts of the plant are often over 30 years old, having been extensively modified and extended over time, for example to accommodate a secondary input fuel or to increase MWe output.

Keeping these plants running reliably and efficiently is the key challenge for the engineering teams in charge. In addition, they need to do so against a background where the plant is likely to be on its downward slope towards full decommissioning. This means it's unlikely to be on the receiving end of multi-million dollar new investment by the parent company.

One might have thought that a global energy business, with generation assets in a string of countries, would have a team of combustion engineers with the experience to tackle any emissions challenge, but the reality is that expertise is very site-specific. So when issues arise that are outside the core competencies of the in-house teams, there isn't a significant resource within the group to whom the in-house team can turn for support.

Increasingly, generators are looking towards hiring emissions reductions specialists to ensure that large combustion plants can continue to operate effectively within a tightening regulatory environment – without recourse to massive capital investment or wholesale replacement of costly

(left) Old low Nox burners at AES Tisza
(above) new low NOx being installed

Case: EdF

Électricité de France (EdF) was experiencing emissions challenges at one of its oil-fired plants just outside Paris, France. The plant had been mothballed for 20 years and EdF wanted a third-party evaluation to see what cost-effective emissions control techniques might be required to make it capable of meeting peak network load. It would also have to be fully compliant with the anticipated 2010 European Union LCPD (Large Combustion Plant Directive) emissions limits – expected to be not greater than 400 mg/Nm^3 for NOx and 50 mg/Nm^3 for particulate emissions.

We sent a three-man team to the plant to spend a week reviewing every aspect of its three generation units. This included comparing key features on the engineering drawings against actual dimensions on the plant (often the drawings don't show latest modifications) and tracking every stage in the combustion process for each unit.

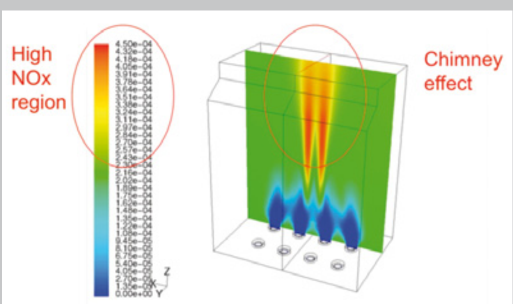
As all three units were configured differently, our report provided a set of individual solutions for each one, in a way that would yield maximum emissions benefit at minimum cost. Of key importance, for example, was the fact that the report confirmed that excellent performance could be achieved without the need to add selective non-catalytic reduction (SNCR) or selective catalytic reduction (SCR) technology to the units. While SNCR or SCR systems lead to bigger NOx reductions, they are relatively costly to add on, since ammonia has to be bought in, and an ammonia storage plant has to be built adjacent to the unit.

Our report also confirmed that availability and reliability of the boilers would not be affected and that minimal changes to the control schemes of the boilers were needed.

Case: AES plant, Tisza

At an AES plant at Tisza in Hungary, we replaced low NOx burners (which had been fitted as recently as 2003) with our own low NOx firing systems. Careful analysis of the CFD model confirmed that a chimney effect was occurring within the furnace (see below).

Through a combination of measures, including modified burners with staged gas nozzles and our own low NOx gas stabilisers, we were able to remove this chimney effect and provide a more even convection temperature and create an environment better suited to low NOx combustion.



Chimney effect as revealed by the CFD analysis

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Case: AES plant, Kilroot

We recently looked to determine the most suitable technologies to achieve NOx reduction at AES Kilroot in Northern Ireland.

AES Kilroot power station is a 520 MW plant, located at Carrickfergus, north east of Belfast. There are two 260 MW coal and oil-fired boilers which are tangential-fired and were already fitted with a low-NOx concentric firing system (LNCFS II). NOx emissions were 648 mg/m_0^3 on coal and 491 mg/m_0^3 on oil. Our target, to comply with the EU LCPD, was <500 mg/m_0^3 on coal, and <400 mg/m_0^3 on oil.

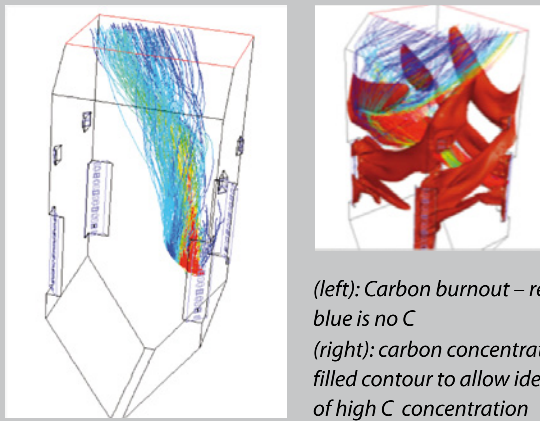
To achieve this, we installed burner modifications, overfire air (OFA) modifications, and coal mill classifier upgrades. Critically, the upgrade had to be achieved without adversely impacting on carbon-in-ash (CiA) levels, while still achieving the desired reduction in NOx.

Overfire air is a way of delivering additional air to the furnace. Our systems can deliver incremental NOx reductions of up to 40%, through the implementation of multiple OFA ports, using either forced draft fan pressure air or boosted air delivery systems.

In this case CFD analysis identified that the OFA ports needed to be re-angled and fitted with smaller nozzles in order to meet the CiA guarantee. Getting the level of CiA right is important because if the level is too high, then the ash cannot be sold on for use as a component within the concrete and cement manufacturing sector, but instead has to be sent to landfill. Needless to say, the financial contrast between deriving a revenue for the CiA and having to pay for it to go to landfill is considerable, running into hundreds of thousands each year.

As well as using CFD analysis to address the combined NOx/CiA challenge, we developed a visual diagnostics method that provided excellent results and insights into the char reaction process (see examples in graphics).

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



(left): Carbon burnout – red is high C, blue is no C
(right): carbon concentration as a filled contour to allow identification of high C concentration

The second graphic shows carbon concentration as a filled contour. This allows for identification of high 'C' concentrations during OFA optimisation.

The graphic also combines an iso-surface of oxygen with coal paths coloured by carbon concentration. This unique type of view shows how the coal particles actually interact with supplied air though either the offset or OFA ports. It was also found that 52% of the CiA came from lower coal injection nozzles. By increasing the amount of air to the lower furnace, the CFD model showed that CiA was reduced.

Several OFA iterations were assessed until an optimal configuration was determined, predicting a significant NOx and CiA reduction. Following completion of the modifications, actual results confirmed a 31% reduction in both NOx and CiA levels burning South African coal; a 47% reduction in NOx and a 69% reduction in CiA burning Colombian coal, and a 22% reduction in NOx achieved in burning oil.

sections of the plant.

Some specific cases from our own experience highlight areas where specialists can help

site surveys

The first stage of any consultation is a site survey (eg see EdF case), which will typically include a thorough review of every aspect of a plant's generation units. The resulting report will detail exactly what is and isn't feasible for emissions control, and at what cost. The company can then make an informed management decision about whether to make an investment to ensure compliance with emissions standards, or not.

Some generators, following the results of a site survey, decide to opt out of the LCPD altogether. This means they do not have to deliver NOx or SOx reductions, but as a consequence, generation time is limited to 20,000 h from the date upon which they opt out. A number of UK power plants have done this, most of which are due to stop operations by the end of 2015.

CFD analysis

After a site survey, a typical next step is commissioning a computational fluid dynamics (CFD) analysis of the plant.

The way CFD works is that around 200 readings are taken at key points within the plant, measuring pressure and volume flowrates for fuel and air, combustion temperatures throughout the furnace, and temperature, pressure and volume flowrates of the flue gases and constituent parts, to name but a handful. The data is then fed into a computer model and the model is then 'run' in the virtual world until the model delivers the same readings as those obtained by the plant during normal operation. Once this point of congruency has been reached, the real CFD work can begin.

By having the plant 'generating' in the virtual world, changes can be made within the computer model to see what impact they will have on other parts of the combustion process. For example, within the model, the operator can change the size of the coal particles leaving the classifier and see how this might impact on emissions.

Using thorough analysis and testing via the CFD process we form a clear view about which components might need to be changed or which operating procedures need modifying to deliver the emissions reductions required by the plant operators.

In this way, downtime can be significantly reduced, expenditure on new components kept to an absolute minimum and the likelihood of good operating performance post-modifications, significantly enhanced (eg see AES Kilroot case).

low NOx firing systems and combustion optimisation

In some cases, existing low NOx firing systems are no longer capable of meeting latest emissions limits and can be replaced with newer systems (eg see AES Tisza case).

Using techniques such as these, emissions reduction specialists are geared up to ensure that generators can achieve emissions reductions as cost-effectively as possible and still seek incremental improvements in efficiencies, throughout the whole combustion and power generation process. **tce**

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