Near zero

With construction about to commence on the Hatfield clean coal power plant, Brian Tinham looks behind the scenes at its integrated gasification combined cycle technology

Technical pointers

- Pre-combustion coal-fired power station carbon capture should be live in the UK by 2013
- Unlike conventional post-combustion CCS, it is almost pollution-free
- Initial firing will be as a combined cycle gas turbine in 2011
- Phase Two will see Hatfield migrate to IGCC burning coal feed syngas
- Plant is pre-engineered to cope with output increase from 286MW per turbine to 302MW
- Dry low NO_x burn will be changed to MNQC (multi nozzle quiet combustor) technology
- The throat area of the Stage One nozzle will be enlarged
- If gasification fails, the whole plant can revert to CCGT operation

With the obvious exception of the global economic crisis and its insidious infection now of the 'real economy', recent months, and indeed years, have seen no greater issue than climate change. Governments and organisations around the world have pledged radical reductions in emissions – most recently with Gordon Brown's insisting that the UK's target for CO_2 reduction must be 80% by 2050. In short, interest in energy efficiency, alternative generation and carbon capture has never been greater.

So, given the importance of coal-fired power generation for the foreseeable future, it was surprising to find UK government opting to pursue only post-combustion carbon capture and storage (CCS) for its competition, announced late last year, aimed at supporting the development of a commercial scale 300—400MW demonstrator, capable of capturing 90% of its CO_2. Four companies – BP Alternative Energy, E.On, Peel Power and Iberdrola-Scottish Power Generation – remain in the running. However, the question for business secretary John Hutton is not which one will win and go on to (hopefully) build that clean-burn plant by 2014, but whatever happened to the potentially cleaner option of pre-combustion CCS?

In fact, that very promising alternative is being actively and independently pursued by none other than PowerFuel Power, which recently selected GE Energy technology for the power island at what will be its 900MW integrated gasification combined cycle (IGCC) project near Doncaster, South Yorkshire, at the mouth of the giant Hatfield colliery. And, ironically, GE Energy gas and steam turbines and associated plant, coupled with Shell gasification technology and Jacobs Consulting engineering, are likely to result in the world's first commercial scale near-zero emissions coal power plant by 2013 – one year ahead of the government's target.

Magued Eldaief, managing director of GE Energy UK, is sanguine about Hutton's choice – noting only that the resulting decisions by E.On and Centrica to put their pre-combustion projects, at Killinghome and Teesside respectively, on the back burner were regrettable. Given the money each of those organisations is said to have lavished on pre-qualifying their plant technology proposals, it's likely that they would use rather stronger language.

That said, with the UK's dependence on burning pulverised coal at existing power stations, a technology choice that enables retrofitable solutions to clean up flue gases makes sense. Although, as Eldaief observes: "It's a pity, though, because with IGCC technology, we're talking about pollution prevention – we don't make the mess in the first place, so we don't have to clean it up – whereas, with post-combustion CCS, the only option is pollution control, with scrubbing and sequestration up to 100 times the volume of IGCC."

Huge potential

It's also the case that IGCC can offer useful by-products, such as sulphur, which is stripped out of the coal during gasification, and hydrogen, which may yet help governments' moves towards hydrogen-based economies. And there is evidence that it could be one of the lowest cost options for cutting carbon from the generation sector – certainly if GE's operating experience is anything to go by. We're talking about more than one million fired hours using high hydrogen fuels, with 26 turbines on a range of plants since the 1980s, including 12 IGCC – five solid fuel and seven refinery waste. GE has also been gasifying materials in the chemicals sector (capturing CO_2 as part of urea and ammonia production processes) and Eldaief says that CO_2 separation and capture is ready to go full-scale.

So let's look at the Hatfield CCGT (combined cycle gas turbine) in a little detail. How, for example, is PowerFuel going to make the technology pay, given the construction and development timeframe, and the higher initial plant investment? The answer is twofold. First, starting in November 2011, Hatfield will burn natural gas, not coal, as a fairly conventional CCGT, involving two gas turbines, two HRSGs (heat recovery steam generators) and a

common steam turbine, driving standard (although beefed up) generator plant – providing early electricity and income. But second, the whole plant is being pre-engineered by Jacobs and GE, not only to accommodate the gasification island – with its acid gas removal plant, sulphur recovery and air separation unit – when it's ready, but also for easy conversion to burning its syngas (synthetic gas).

Terry Raddings, GE's technology solutions manger Europe, explains that syngas is produced by gasifying coal – in Hatfield's case, provided directly from its own mine, the only one to have re-opened since the decline of coal mining in the UK, and with an estimated 40 years' worth of fuel on tap. "Shell's gasification process involves an exothermal reaction, using oxygen, steam and coal feeds, and producing syngas – around 60% hydrogen, 35% nitrogen, a small amount of carbon monoxide and less carbon dioxide – along with heat, which we'll integrate back into the cycle."

From an engineering perspective, as a pure CCGT plant, Hatfield's gas turbines (two GE 'F' class plants) are rated at 286MW each. However, when the site switches to syngas, because of that fuel's lower calorific value and increased exhaust gas moisture, turbine firing temperature will be reduced and mass flow increased, resulting in power output rising to 302MW.

Engineering preparation

"The idea is to make the baseline maintenance regime the same with syngas as for natural gas," explains Raddings. "So when we convert to syngas, we'll need to do a couple of things," he adds. "First, we'll need to swap out our standard dry low NO_x natural gas burner technology and install MNQC [multi nozzle quiet combustor] diffusion type plant, controlling NO_x emissions to 25ppm at 15% oxygen, by injecting a diluent, in this case nitrogen. But second, we'll also have to increase the throat area of the stage one nozzle in the gas turbine to allow that greater mass of gas to flow."

One interesting point arising is that, since the firing temperatures will be lower with syngas, the design doesn't call for costly exotic materials in the turbine section – so no single crystal blades or special coatings, for example. Another is that, because the plant is being designed such that, if the gasifiers fail (meaning nitrogen also fails, since air separation is integrated with the gasifiers), it can continue generation by reverting to natural gas – only now with steam injection provided from the turbine combined cycle for NO_x control. Raddings says that, although power output per turbine then drops to about 282MW (because of higher heating values and reduced mass flow), that changeover does not alter the plant's maintenance baseline.

Beyond all that, Raddings mentions additional ancillary plant requirements, such as the nitrogen skid, steam injection skid and syngas module. Systems will also need to be designed for safety in line with hydrogen fuel, so taking into account NACE and ATEX standards. He also explains that upfront engineering extends to the gas and steam turbine generators, which are slightly oversized to harness the additional power on changeover from natural gas to syngas. And, similarly, the HRSGs are being modified to integrate steam from the exothermic gasification process into the combined cycle. "These are being engineered from day one, because it makes no sense to modify the boilers in situ, two years down the line. Upfront integrated engineering is the key to making IGCC economically feasible through phased implementation," he says.

For Powerfuels CEO Richard Budge, it's very simple: "Our objective has always been to build a near zero emission power plant next to the Hatfield Colliery… With GE CCGT technology, we will have the fuel flexibility to respond to policy changes and decisions to have this plant available for carbon capture and storage as early as 2013, and support an early implementation of clean coal generation in the UK." And you can't say fairer than that. PE

emissions

Left: Terry Raddings on-site at Hatfield
Above and below: GE power plant in Tampa, Florida – its first IGCC plant using 9FB turbine technology