Power play

Combined heat and power, and energy storage plants are the biggest games in town, where renewables are concerned. Brian Tinham looks at some of the latest developments

Few would disagree with the imperative for engineers to work towards reducing our dependence on fossil fuels and bearing down on carbon emissions. And one of the most obvious ways to achieve both, where power generation is concerned, is to favour any of the combined heat and power (CHP) technologies, subject to scale, where at all feasible.

The energy recovered as heat makes such projects far more efficient and hence also far cleaner than 'conventional' power plants where that by-product is simply rejected. Also, as long as a continuous and significant requirement for the heat output is proven, the capex and opex costs, too, are very favourable.

However, where there is no immediate and ongoing requirement for additional local energy – and for reciprocating engine micro- and mini-CHP plants, that heat demand needs to be at least double the power output – the maths rapidly fall down. It's also the case that the vast majority of CHP plants – whether CCGT (combined cycle gas turbine), at one end of the spectrum, or modified diesel engines at the other – continue to be driven by fossil fuels. So while the rate of usage is mitigated, limited resources are still being consumed.

The trick, with renewables, is to manage variability and time phasing

Another way to go green is to move as much energy production as possible over to any of the range of renewables. The issues then range from maturity and also applicability of the technologies for a particular application and location, to stability of the resulting energy supply. The former are beyond the scope of this feature, but fluctuations with the latter explain users' tendency to steer well clear of renewables for baseline or even peak power, and instead to consider them as supplementary sources. They also explain the current focus on energy storage plants that could deal with the limitations of intermittent supply – hitherto focused on expensive and geographically limited hydro power.

But all that looks set to change, due to one company's dogged determination to overcome this hitherto intractable problem. That firm is Highview Power Storage and at heart its technology uses nothing much fancier than compact liquefaction plant to capture redundant energy as liquid air, before expanding it out via a turbo-generator as power on-demand. What's more, last July Highview switched on its first operational pilot, hosted at SSE's (Scottish & Southern Energy) Slough Heat & Power plant near Heathrow and connected to the National Grid under G59 rules.

This plant has now successfully notched up more than 150 hours – equivalent to two years' UK reserve – operating under the seasonal 'triad' lowload factor peaking service at up to 350kW. As a result, Gareth Brett, Highview CEO and veteran of the electrical utilities sector, forecasts the sweet spot for full-scale units at around 50MW, with 250MWH of storage, allowing for four to eight hours of generation. He also puts future kW costs at the £500–1,000 mark and adds that, since this plant design uses mature equipment, the global supply chain should offer no surprises, with predictable pricing and industry standard lead times.

Game-changing plant

Sounds too good to be true? Well, no – and this hasn't happened overnight. Highview COO Toby Peters explains that development started back in 2005, with technology assistance from the University of Leeds, leading to a 5kW R&D rig for initial-phase plant and performance modelling. "The point is that liquefaction is very mature, but we also needed to prove that you can use liquid air to develop power, and do so cost effectively to meet the power-time shift requirements of renewable generation," he says.

Walking through the Slough pilot – which began procurement in 2009 and is 100 times larger than the initial rig – the front end starts with harnessing spare energy to drive compressors, stripping out water and CO_2 via a standard molecular sieve flash adsorbent module. Compressed air then moves into a Claude refrigeration cycle – expanding the gas through a cryogenic turbine to rapidly cool it and drive a refrigeration heat exchanger. That produces liquid air at -196°C, which is stored in a large, double-insulated cryogenic tank, rented from BOC.

"The front end is fairly standard liquefaction plant, with a bespoke chiller and cold expander from Cheng Du Air, driven by Atlas Copco VSD compressors. Nearly all of this plant is run by variable speed drives, because they help us fine tune control," explains Brett. And he adds that, on the instrumentation and control side, Blackburn Starling built the system for the liquefier and balance of plant, with the exception of the downstream power turbine, which was handled by PES (Pneumatic and Electrical Systems), using Siemens PLCs.

Moving on through the process, when the plant sees power demand, liquid air is automatically retrieved and pumped to high pressure, using Cryostar reciprocating pumps and a cryogenic evaporator, with ambient and low-grade waste heat added from the power station, via a heat exchanger, to enhance performance under an open-ended organic Rankine cycle. High pressure air is then expanded out through a Concepts Nrec four-stage, radial inlet turbine, dropping pressure from 70bar eventually down to half a bar, with intermediate stage heating and each driving a clustered gearbox. That, in turn, powers a two-pole synchronous ABB generator, running up at around 3,000rpm.

Gareth Brett, Highview CEO and veteran of electrical utilities, surveys his new energy recovery pilot plant

Emerson Smart Energy promises cost savings on renewables

Emerson Process Management has kicked off what it's describing as a global programme, combining its industrial energy expertise with energy management technology. Dubbed the Smart Energy initiative, it is aimed at plant managers wanting to improve their renewable fuels usage, while also cutting costs and reducing emissions.

Steve Sonnenberg, president of Emerson Process Management, makes the point that energy comprises around 30% of most plants' operating costs – so, with rising prices, the heat is on to make better use of waste fuels, biomass etc. Hence Emerson's new Industrial Energy Group, which he says will focus on modernising and improving the performance of power houses and on-site utilities, while also streamlining how plants consume energy.

Sonnenberg explains that at the heart of Emerson's initiative is "a new integrated technology platform that can change energy economics". He refers to the company's True Energy technology – patent-pending software for calculating the calorific values of fuel sources – which can make green energy production predictable.

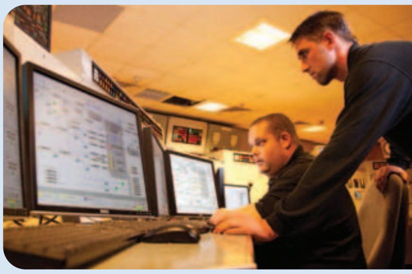
"Our Combustion Control platform reinvents the current model of combustion management, which has been around since the 1920s and is still in practice today," comments Chip Rennie, director of industrial energy for Emerson. "This brings about nothing short of a reinvention of combustion models, which will make the prevalent use of low-cost fuels, like biomass, achievable and sustainable."

According to Sonnenberg, what's on offer is proprietary software, combined with Emerson's plant control systems – for the first time enabling power houses and utilities to use the most available and affordable renewable fuels. Input streams might include wood waste, food by-products, animal waste and manufacturing by-products.

"We have seen tremendous growth for certain projects, such as biomass-to-energy conversion, where we have many users running on renewable fuels 95% of the time," states Sonnenberg. And he points to applications ranging from increasing steam production from scrap wood at a commercial power facility, to increasing efficiency and stability of by-product gas burning at a steel mill.

"Emerson's work at our Port Talbot steel mill is helping us make better use of indigenous fuels, such as blast furnace gas and coke oven gas," confirms Andrew Rees, manager of a boiler upgrade project for Tata Steel. "The improved controls are part of a comprehensive energy management project that's expected to reduce power house energy consumption by 3–5% and help us ... become energy self-sufficient."

Technologies being fielded include Emerson's SmartProcess boiler and energy management software. SmartProcess Boiler, for example, provides real-time combustion controls that handle the inconsistent nature of waste fuel sources, automating plant management during changes in fuel calorific value or availability.



Smart energy in action at Port Talbot steel mill

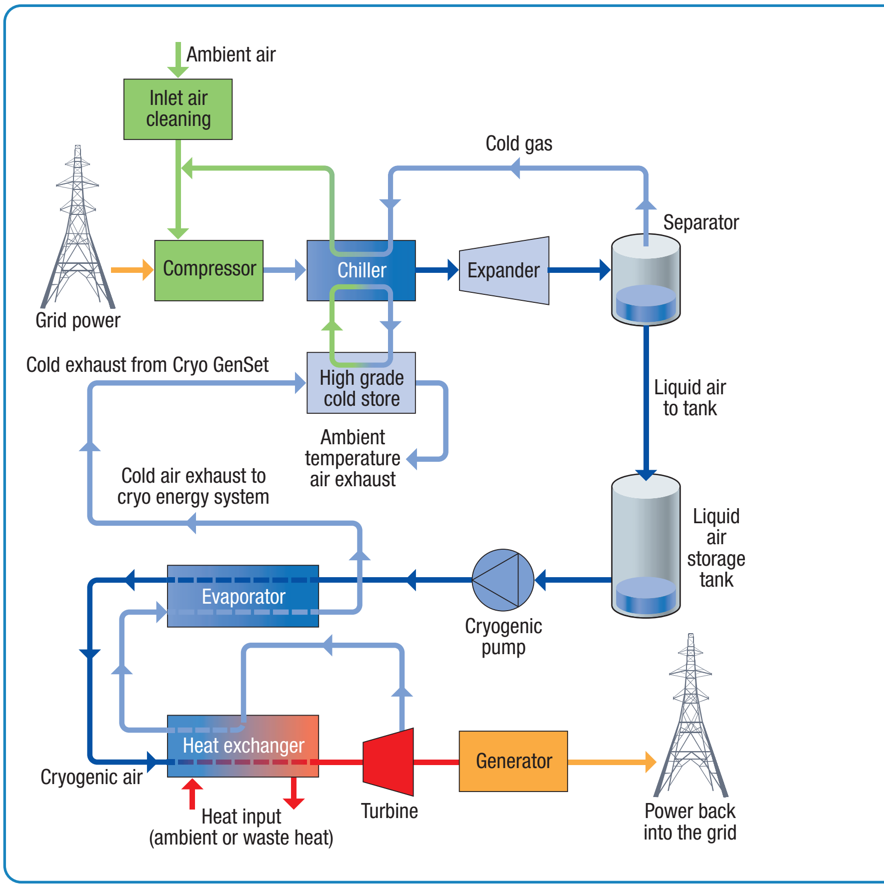
Brett makes the point that full-scale plant would use standard, off-the-shelf process gas expanders from suppliers such as Atlas Copco, GE and Siemens. Either way, though, exhaust gas leaves the turbine at half a bar and provides evaporator pre-heating to minimise external heating.

"The only remaining output is a high quality, clean, dry gas stream that is super cold – and we use that to cold-charge a packed bed regenerator, which, in turn, helps drive the chiller at the front end of the process, on demand," he says. "It's a long feedback loop, but it allows us to minimise compressor power at the liquefier. Similarly, we plan to store heat from the front-end compressors to improve the heat balance on the back-end power generation side at the heat exchanger, when it's running."

Elegant fit

It's an impressive development – both because of its simplicity and its elegance. Brett suggests that it's a natural fit not only for shaping renewable plant outputs, but also for running alongside exothermic chemical plant, where the ready supply of low-grade heat could drive useful energy recovery and power. "Equally, utilities, transmission system operators and energy-from-waste plants can benefit," states Brett. "This should be an easy next step for them: supply chains to assemble larger units are in place, and all the components are mature, with well known O&M costs. Also, there are no obvious challenges, in terms of planning consents. The process is zero emissions and it's not terribly noisy."

So what about those costs? "Price point is sensitive to configuration, because the three main components – the charging liquefier, energy store tank and discharge power turbine – are all broadly independent and can be sized to suit the application," explains Peters. "For example, quick-charging plant will have a higher capex than plant designed for trickle charging and rapid discharge, because of the cost of the liquefier. So, if the plant is designed to solve problems at a grid level, as a power reserve application, it's quite cheap. But if it was at a wind farm, it would be more expensive, because it's essentially daily cycling."



Peters' best guess: "£2,000 per kW for early adopters on daily cycling, reducing to £1,000 or less when this plant is mature. And roughly half of those numbers for non-daily cycling." PE

E.On's CHP site improves efficiency by 50%

Although CHP (combined heat and power) plants are inherently efficient (easily 84%, compared with figures as low as 30% for some thermal power stations), opportunities still remain to improve existing plants. E.On's CHP site in Stoke-on-Trent, for example, is now on track to make energy savings of 51%, as a result of an uprated compressor installation.

Mattei installed an AC30sH compressor – the smallest of its 30kW units – as well as efficient dew point-dependent switching devices for two ancillary dryers on the £40 million plant, which comprises a gas turbine, heat recovery boiler and steam turbine, together capable of producing 60MW of electricity and 60 tonnes per hour of steam.

Neil Price, performance co-ordinator at E.On, explains that the plant supplies both electricity and steam to a co-located Michelin tyre factory. To ensure security of supply, the plant has three standby boilers, which can each produce 20 tonnes of steam per hour, while the grid provides back-up electricity. Additionally, the boilers are capable of using fuel distillate, as well as gas, should the need arise.

Mattei compressors have been operating at the site for almost a decade, supplying instrument air to both the gas and steam turbines. However, when Mattei carried out a data logging exercise, it found that replacing one of the two existing AC2030H compressors with the more energy-efficient AC30sH unit would make a substantial difference.

Price states that Mattei had a short window of opportunity to install the new equipment, while the turbines were undergoing scheduled maintenance. He also says that the firm had to make modifications to the steel plant container, including improvements to access, ducting and pipework.

"We welcomed Mattei's review of our compressed air system and the fact that we've been able to improve efficiency by around 50%," comments Price. "Mattei has also demonstrated that its team is capable of working within very tight parameters, in terms of timescales, health and safety, and access."