Downsizing CHP

Combined heat and power has come a very long way since Battersea Power Station. Dr Tom Shelley looks at some of the advances and offers engineering advice

While using waste heat from electricity generation to heat homes is hardly a novel idea – London's Battersea Power Station in London heated much of Pimlico, across the river, decades ago – today's trend is all about much smaller scale for factories, offices and even individual homes.

Technologies underpinning this development centre on low-cost electronic controls that can merge the power from local generators with the mains – locking peaks and troughs of the alternating current. Extracting waste heat from any form of engine driving any form of generator and harnessing it, typically to heat water, is then relatively easy.

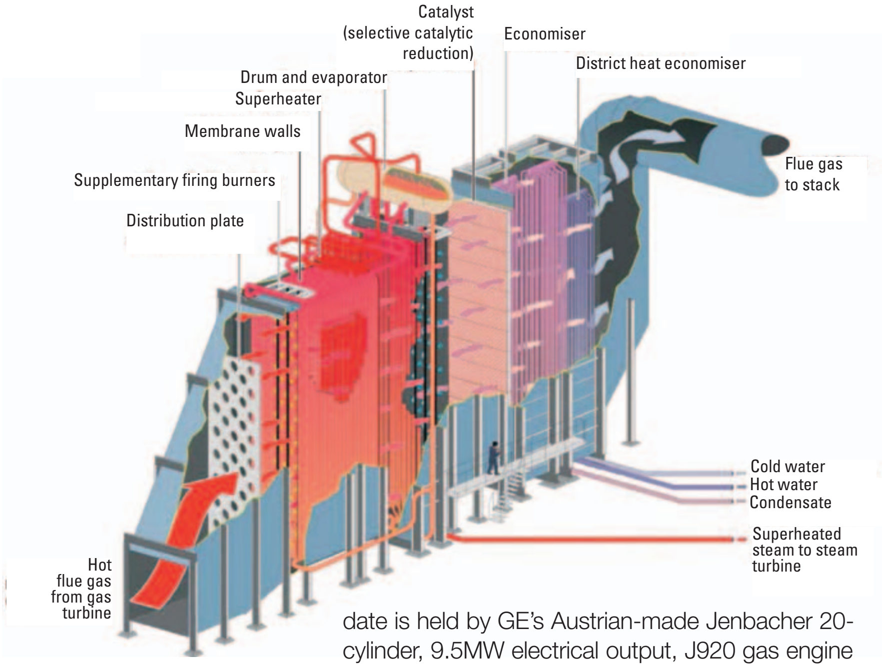
Then there is the politics – and government appears increasingly keen on both local power generation and maximising energy usage. Addressing Integrated Energy 2010 (the Combined Heat and Power Association's annual conference last November), Climate Change Minister Greg Barker talked of encouraging communities "to take up the challenge of decentralised energy". For Barker, micro generation and community scale installations are critical in the new energy economy. "From homes to hospitals, schools to factories, locally generated heat and power will bring a new layer of cleaner, more diverse energy into the mix," he said.

Barker made no mention of funding to encourage development, but did announce a new Community Energy Online project, which he described as an Internet portal for local authorities and community groups that want to develop smaller scale energy schemes. Whether the thinking extends down to the 1kWe of electricity and 1kW of heat that emerging CHP technologies can scale down to is unclear, but the direction is encouraging.

That said, apart from fuel cell-based systems and some laboratory technologies using solid state devices that transform heat directly into electricity, all current installations still rely on an engine driving a generator. This can be an internal combustion engine (diesel or spark ignition), a gas turbine or a Stirling engine – with the engine cooling water and/or exhaust used to generate hot water or boiler steam pre-heating, via a heat exchanger.

The record efficiency for a conventional engine to

Siemens concept plant: gas turbines, combined with heat recovery steam generators, are seeing increasing use across Europe



CHP with gas turbines requires heat recovery from the exhaust gas – as in this installation in Rya, Denmark

date is held by GE's Austrian-made Jenbacher 20-cylinder, 9.5MW electrical output, J920 gas engine generator set, which boats 48.7% electrical efficiency, producing hot water at 90°C or 100°C for district heating and returning it to the cooling circuit at 70°C. Thermal efficiency is said to be about 90%, and Dr Volke Schulte, general manager engineering, says that figure arises from using, first, a two-stage turbocharger with an intercooler to raise the gas-air charge pressure and, secondly, electronic controls to optimise the ignition timing.

Sized for success

German-made Viessmann CHP engines also run successfully on natural gas and biogas, but the firm points to poor specification practices as causing problems. Commercial sales director Nigel Jefferson and marketing manager Darren McMahon say that installations don't always live up to expectations, because they are not sized correctly for heating – only for electrical demand. However, since power is usually cheaper from the grid, and these engines produce twice as much heat as electricity, it only makes sense for plants in the UK to generate electricity, if they are also using the heat. They also need to run at least 6,000 hours per year, or 16 hours per day, to make economic sense.

Incidentally, Jefferson also says that, in retrofit installations, it has found water circulation pumps tend to be oversized – meaning that pumping is too fast, so cooling water temperatures are higher than 70°C and the engine cylinders are not being cooled adequately.

Nonetheless, Viessmann does have satisfied customers in the UK, including six installations for the NHS and a 70kW electrical output generator set that supplies 115kW of heat to a swimming pool in a sports centre run by the Ministry of Defence. Engine generator sets available range from 18kW electric and 36kW thermal to 401kW electrical and 549kW thermal. Interestingly, service intervals, which had been just 2,000 to 3,000 hours, have now been extended to 6,000 hours on 2011 models, and major overhauls only once every several years.

Elsewhere, Ener-G offers gas, biogas and biodiesel engine-based CHP packages in the range 4kW to 500kW electric (in fact, up to 5MW bespoke). Sales director Anthony Mayall says the firm works with engine suppliers, including MAN, Perkins, Caterpillar and MTU. "Key to success is matching the installation to the base load of the plant," he says – adding that Ener-G always examines a year's worth of usage data in its feasibility studies. For Mayall, the 'magic number' to ensure economic viability is running at least 17 hours per day, but the preference is 24/7.

One installation commissioned in September last year was the energy centre for the new Museum of Liverpool. The firm installed two 770hp CHP gas engines and two 385hp CHP engines running on biodiesel, in the Grade Two listed ex-railway building. Mayall says that this mix of engines was chosen because, initially, the customer could not get enough power from the gas grid, but also diesel engines are better at quickly assuming large loads after a 'black start', where gas engines need load to be applied incrementally, 30% at a time.

As well as generating 2.3MW of electrical power, this installation produces 2.2MW of heat or 1.6MW of cooling via an absorption chiller, which use lithium bromide solution (not to be confused with adsorption chillers, which use silica gel). Mayall suggests that steam raising from engine exhaust is only economically viable, if engines are producing more than 500kW electrical output.

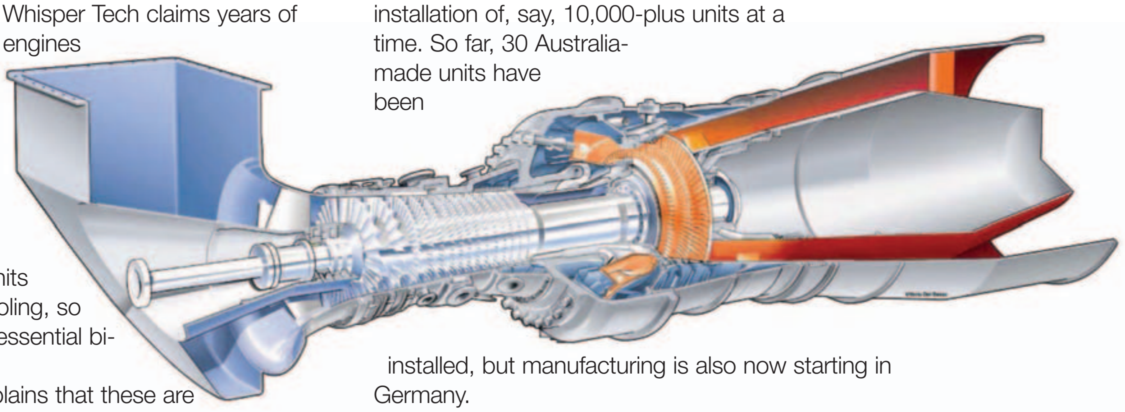
Meanwhile, stepping up a level in the CHP hierarchy, Siemens supplies gas turbines for applications in the range 5–47MW, where there is plenty of heat available for steam raising from the exhaust gases. In this case, heat can be used to produce process steam and/or hot water, but can also generate additional power through a steam turbine in a conventional cogeneration, CCGT

(combined cycle gas turbine) arrangement.

Hanno Garbe, senior sales manager industrial power turbines, says that three Siemens turbine CHP installations have been installed in the UK – one at a paper industry plant, another at the William Grant & Sons whisky distillery in Scotland (producing 5MW of electrical power and 12,500kg/h process steam at 10bar). Overall efficiency is 84%, he says.

Then, dropping down the scale, Stirling engine micro-CHP units, which have been around for a while, offer the advantage of quiet operation, but the disadvantage of depending on efficient heat transfer, since combustion is external to the working fluid. New Zealand-based Whisper Tech claims years of success with Stirling engines that use nitrogen as a working fluid in a four-cylinder configuration, with mechanical motion transferred to the generator through a 'Wobble Yoke'. Its units depend on water cooling, so hot water is also an essential bi-product.

The company explains that these are best in off-grid applications for remote locations, including on motor yachts, but adds that they are also now available on-grid for houses. A pre-commercial ac on-grid model has been trialled in Germany, the Netherlands, France and the UK for the last three years. Recently, however, Whisper Tech entered a joint venture with Mondragon in Spain, forming EHE (Efficient Home Energy), which has been granted the WhisperGen manufacturing and distribution rights inside the EU. Word is we can expect a new Stirling engine micro-CHP system soon.



Fuel cell scale

While fuel cells to power motor cars still look futuristic, progress has been made with developing fuel cell stacks for fixed installations, including CHP plants. The attraction is their 60% electrical efficiency, which is considerably higher than the best achieved by an internal combustion engine.

As an aside, Jenbacher is looking for 54% from its IC engine when it incorporates technology from GE's recent acquisition of Florida-based Calnetix Power Solutions. The latter specialises in converting waste heat to electric power, using a closed organic fluid Rankine cycle, which warms the HFC fluid so that it boils and drives a turbo expander.

Meanwhile, Ceramic Fuel Cells is an Australian company that has been developing fuel cells run on reformed natural gas (whereas almost all successful fuel cells developed so far run on hydrogen). Paddy Thompson, general manager for the UK, says that, in its BlueGen unit, reforming is undertaken in the unit itself at 700–750°C. The basic units produce up to 2kWelectric, with small amounts of heat at 120°C for hot water.

Cost is estimated at 5–5.5p/kWh, which is well above prices charged to large-scale industrial users, but well below the 11.2 p/kWh retail rate. According to Thompson, applications are likely in shops, pubs and restaurants, as well as in office blocks, where a unit could be installed on each floor next to the washrooms, with the hot water used locally, while generated power reduces the overall draw from the national grid. In the longer term, he foresees mass installation of, say, 10,000-plus units at a time. So far, 30 Australia-made units have been installed, but manufacturing is also now starting in Germany.

As for lifecycle maintenance, Thompson claims that stacks should last five years before needing replacement. All units are controlled and monitored over the Internet, with automatic maintenance reminders and fault alerts, and maintenance visits required once yearly. Incidentally, neither maintenance nor stack replacement require shutting the unit down, and the company claims that each unit installed in the UK will save 3.3–5.8 tonnes of CO_2 per year, based on DECC's figures for the carbon intensity of grid electricity.

Meanwhile, its Danish rival Dantherm, which has started installing micro-CHP plants on a pilot basis – each producing 1kW of electricity and 1kW of heat – uses SOFC (solid oxide fuel cells). These were developed by Risø DTU in Lyngby, Denmark, under a strategic agreement with Topsoe Fuel Cell, which developed the fuel cell stacks (Topsoe PowerCores) to the commercial stage. Topsoe Fuel Cell then partnered with Dantherm Power, which sells small CHP plants. So far, Dantherm has installed two units and is in the process of installing five more. Experience from these will go into 15 additional units, to be manufactured and installed this September, leading to full-scale production in 2012.

Says Dantherm's Jesper Themsen: "In 2012, we believe that SOFC micro-CHP plants will be affordable and have the desired properties, allowing people to easily replace their old furnaces with an SOFC micro-CHP plant." Fuels will initially be natural gas, but later could be methanol or liquefied petroleum gas or biofuels. PE

Left: Siemens 45MW SGT-800 gas turbine may be used independently for power generation or, as above, in CHP mode

Pointers

- The preference for most CHP installations is at least 17 hours per day running
- Viessmann CHP engines running on natural gas and biogas need to be sized on heat, not electrical, demand
- Its engine generator sets range from 18kW electric and 36kW thermal to 401 electric and 549kW thermal
- Ener-G offers gas, biogas and biodiesel engine-based CHP plant in the range 4kW to 5MW electrical output
- This company's CHP engines are powering the new Museum of Liverpool
- At a micro level, fuel cell stacks now look promising for shops and even houses