Capabilities on project:
Energy
Environment

Section D

Examines the feasibility of conversion and utilisation of the existing Rolls Royce power plant in factory Lane

A single large CHP plant is often difficult to develop in a town centre area due to the lack of a suitable site and the relatively high value of the land area. However in Croydon this option can be pursued because there is an existing power station close to the centre within an industrial zone.

There was a power station in Croydon for many years however the old station was closed down and in 2005 a new station commenced operation. This is owned by Rolls Royce Power Developments Ltd and is operated by Rolls Royce Energy. It comprises an open cycle gas turbine, the Trent 60 and generates approximately 50MWe.

Discussions have been held with Rolls Royce (on October 12th 2009 and December 16th 2009 with the HSE and Asset Management Director Mike Strutt) to determine the commercial and technical issues associated with its conversion to operate as a CHP plant.

Existing contracts

The plant is currently selling its output under two contracts running in parallel. The first is for Short-term Operating Reserve (STORE) and the second is for winter peak period grid support. The STORE contract runs until April 2011 and the winter support contract runs until April 2012. Beyond this date new contracts could be negotiated for the more extended running that may arise with operation as a CHP plant.

The STORE contract runs through the summer and is designed to meet sudden peaks in demand when the unit is required to start-up and run at full output under instruction from the National Grid. The winter support contract is designed to provide power typically in the peak winter period from 3pm to 9pm each day of the week.

Suitability for CHP operation

Although the existing Trent is currently running less than 1,000 hours p.a. it would be possible to extend its running hours. The Trent has been installed as a CHP plant at Rolls Royce's own site in Ansty which runs as base load.

The Croydon plant operates under a permit from the Environment Agency and this permits up to 5,250 hours p.a. operation. Emissions from the plant have been monitored over the last 3 years and have been shown to be within the limits of the permit. The existing stack is 67m high which ensures a high degree of dispersion of pollutants.

Heat recovery options

There are two ways in which the unit can be converted to CHP:

As open cycle

This option involves the addition of a waste heat recovery boiler which will use the exhaust gases from the gas turbine to produce hot water for direct use in district heating. The flow of exhaust gases will be controlled by means of dampers either through the boiler to a new stack or, if heat is not required through to the existing stack. The dampers will enable a degree of control of the flow of exhaust gases through the boiler so that the output can be controlled. There appears to be sufficient space on the existing site to install the boiler and new stack to the south-west of the existing stack. As all of the heat is available as high temperature gases the district heating can be produced at temperatures up to 125°C which is an advantage compared to gas-engine CHP. Higher flow temperatures will reduce the cost of the heat network and reduce the cost of absorption chillers if these were to be used within the system.

As Combined Cycle

In the combined cycle mode, the exhaust gases are used to raise high pressure steam which is then used in a steam turbine to generate additional electricity. Heat can be provided either by extracting steam from the steam turbine or by using a back-pressure steam turbine where the steam is lowered only to a pressure to suit the temperature of the district heating supply. A combined cycle plant generates additional electricity so it is thermodynamically more efficient however the plant is much more complex, more costly and requires substantial space for both the steam boiler, the turbine and heat rejection equipment. Our current view is that this option could only be implemented if additional adjacent land could be made available.

CO_2 emissions

The efficiency of the existing plant in electricity only mode is about 36%. This is similar to that which would be obtained from gas-engines. This efficiency is relatively high for gas turbine CHP partly because the Trent is an efficient aero-derivative and partly because the gas supply pressure is a minimum of 19 bar which means the power used by the gas compressors is relatively small (total parasitic load is estimated at 1MWe). When heat is extracted during periods when the gas turbine would have been operating under its current contracts the heat is produced with no additional CO_2 emissions and so has zero CO_2 content. When the gas turbine is operating at other times the CO_2 reductions achieved will be similar to that obtained from gas-engines.

Benefits of adapting the existing RR Trent as a CHP plant

In comparison with the other CHP options there appears to be a number of advantages to the use of the existing power station:

- Lower capital costs as the prime mover already exists and the costs are only related to the heat recovery boiler; other costs avoided are the cost of the land, the grid connection and fuel supply

- Low operating costs as for much of the winter the plant would be running commercially so that the heat production cost during these periods is effectively zero

- Very large potential for heat supply, up to about 35MW of heat

- Gas turbines have lower NOx emissions than gas-engines and the high stack means pollutants are well dispersed so a net improvement in air quality would be expected from CHP operation as emissions from low level boilers are displaced.

The low cost of heat and low capital costs will need to offset the costs of the heat transmission main required to transport the heat to the town centre area.

Additional potential economic benefits

The plant is large enough to operate within the EU Emissions Trading System. Under the current phase, if the plant is converted to CHP operation additional free allowances can be claimed. This would provide an additional income to the site which would assist in financing the waste heat boiler.

A second incentive is that part of the electricity output will qualify as good quality CHP and will then qualify for exemption from the Climate Change Levy when it is sold.

Thermal storage

Heat demands form buildings vary significantly over the day and over the year. The heat output from a CHP plant can be varied over the year by operating fewer hours in each day and storing the heat produced for use over the 24 hour period or by using multiple smaller units in combination with turndown of the plant. The gas turbine is not efficient at part load and is likely to be relatively large in relation to the heat demand especially in the early years of the scheme. The gas turbine currently operates in the winter for about 5 hours per day between 3pm and 9pm. Whilst there will be some heat load in this period the heat demand of commercial offices occurs mainly in the morning. A significant amount of thermal storage will therefore be needed to store the surplus heat produced in the afternoon and evening for use the following morning.

The store could be installed either centrally at the gas turbine or remotely within the load centres in the zones or a combination of these approaches. Initial analysis indicates that the lowest cost option would be to locate thermal stores throughout the heat network operating at low temperature (95°C maximum flow temperature). This minimises the cost of the stores and improves reliability. The space available at the RR power station is also limited. The capacity of the transmission main from the RR power station will be sized to deliver the maximum heat output from the gas turbine CHP plant.

Heat recovery system

The exhaust gases from the gas turbine contain almost all of the heat rejected and a heat recovery boiler has been sized to deliver around 35MW of heat by cooling the gases from 444°C to 180°C. Further heat could be extracted using lower exhaust temperatures however this may impact on the dispersion of pollutants and may require a larger and taller stack.

The company Greens Power Ltd was approached to provide an outline design and budget price. Their proposals comprise:

A finned tube heat exchanger over which the gases will pass with dimensions:

Tube length 7m, 40 tubes per row, 6 rows high

The overall plan dimensions would be 8.3m long, 4.1m wide, 1.9m high

Operating temperatures

The advantage of the gas turbine is that all of the heat is available at high temperature and so there is a wide choice available for operating temperatures.

To minimise the cost of the heat network the return temperature needs to be as low as possible. This temperature is however determined mainly by the return temperature of the buildings heating systems. Existing buildings will typically be designed with a 71°C return temperature and so allowing for a temperature rise across a heat exchanger at the point of connection the DH return temperature would be about 75°C. New developments could be designed with lower temperatures around 40°C resulting in a DH return of 45°C. The overall network return temperature will therefore vary depending on the balance of new and existing buildings connected. It is also possible that the return temperature of existing heating systems can be reduced as the heat emitters are likely to be oversized. We have therefore selected a return temperature of 65°C as being a conservative assumption if lower temperatures are achieved this would improve the economics of the scheme.

The upper limit of the flow temperature is determined by the life of the polyurethane foams used in pre-insulated district heating pipes which is around 130°C.

A high flow temperature will result in lower flow rates and a lower cost network. The volume of water needed to store a given quantity of heat will also be less. The cost of storage will however be higher as a pressurised store will be needed increasing costs.

For the initial analysis we have assumed a 95°C flow temperature for the network within the town centre zones as this is compatible with gas-engine CHP and will result in lower heat losses and thermal store costs.

For the transmission main from the RR power station there will be benefits in minimising the flow rate by increasing the flow temperature to 125°C so that the pipe size can be minimised. Heat losses will be higher but these will be relatively small with the large diameter pipeline.

Business Case Assumptions

The business case for the RR power station CHP option assumes that the operating hours remain at 5 hours per day from November to March only. This restricts the amount of heat available and so it has been assumed that the supply will be to Zone 1 heat demands only. Although in principle there is no significant cost to RR for supplying heat a heat purchase price of 0.5p/kWh has been assumed in the model to provide an incentive. Capital costs for the heat recovery boiler and transmission heat main and pumps have been included.

If the district heating is expanded to Zones 2 and 3 then it would be possible to increase the operating hours of the gas turbine CHP and the additional operating costs would be met by an increase in the heat purchase price. An alternative would be to install a gas-engine CHP in addition to the gas turbine heat supply to operate in summer and in the peak winter period.