Minworth STW CHP Replacement

installation of three new combined heat and power units

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Minworth is Severn Trent Water Limited's (STWL) largest sewage treatment works serving the city of Birmingham with an estimated population equivalent of 1.75 million. The site's existing fleet of 9 (No.) combined heat power (CHP) units is an important source of renewable energy for STWL, annually generating around 55GWh of electricity each year, which equates to approximately 26% of STWL's total renewable energy generation. The plant uses biogas generated through the anaerobic digestion of both indigenous and imported sludge. The heat generated by the plant is reused on site to provide thermal energy to maintain the anaerobic digestion process and liquor treatment plant.

Completed CHP installation including exhaust flue stack - Courtesy of Mott MacDonald Bentley Ltd

Project drivers

The site's existing 7.5MW fleet of 5 (No.) 11kV Waukesha CHP engines were at the end of their design life and posed a risk of failure and therefore loss of revenue. One of the existing CHPs had already failed and been deemed beyond economic repair. In order to cover this shortfall in generating capacity, STWL had hired in a temporary Caterpillar CHP to assist with the 4000Nm^3/hr flow of biogas and maintain a minimum capacity requirement of 6.7MW of CHP to provide heat and electricity for the site.

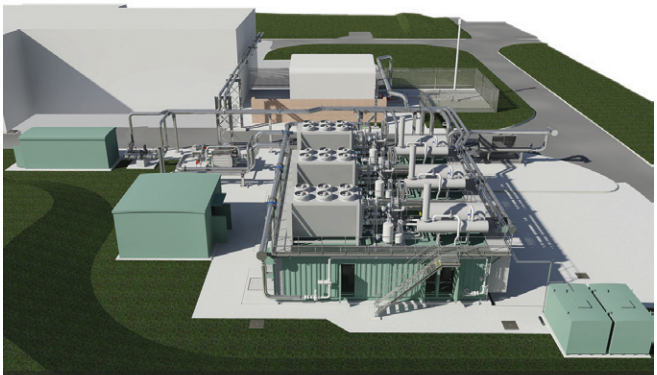
The scheme was set up with the intention to replace the aging fleet of Waukesha CHPs with 3 (No.) new, high efficiency HV, container-housed Jenbacher 4 Series CHP units. The scheme will deliver benefits to STWL by providing an increase in reliability and efficiency of the power generation capacity at Minworth, in addition to approximately £412,000 in annual OPEX savings.

These savings will be gained from an additional 2GWh of energy generation as a result of the higher efficiency CHPs and ancillaries, and reduced maintenance costs compared to the old fleet of Waukesha's.

However, three Waukesha units will be retained as standby/assist units for use when there are peaks of biogas production, during times of planned engine servicing and during triads. The Caterpillar CHP will no longer be required once this project is complete and is to be off-hired by STWL.

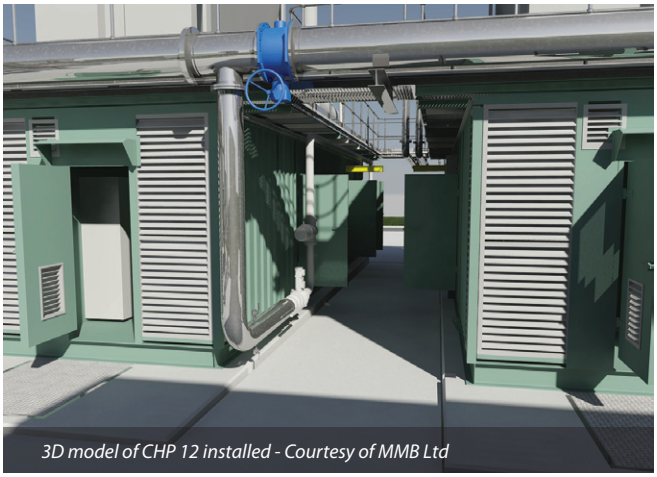
Scope of work

Mott MacDonald Bentley (MMB) was contracted to design, procure, install and commission the necessary biogas, process heating water, low voltage (LV) power and control, high voltage (HV) power output and engine lubrication oil infrastructure to connect the 3 (No.) new



Three dimensional render of the CHP installation. Exhaust stack omitted Courtesy of MMB Ltd

CHPs 10, 11 and 12 with process water pipework suspended from cantilevered access platform - Courtesy of MMB Ltd



3D model of CHP 12 installed - Courtesy of MMB Ltd

Photograph of CHP 12 installed - Courtesy of MMB Ltd

CHP engines to existing site supplies. Also included in MMB's scope of work was the permanent electrical decommissioning of 2 (No.) Waukesha CHPs, including the obsolete unit, in order to facilitate the new HV connections into the existing HV substation via a new HV switch panel. To drive programme and budget efficiencies STWL placed the contract for the new CHP engines directly with their framework supplier Clarke Energy Ltd.

Electrical works

As part of the project a new CHP Interface motor control centre (MCC) was designed by MMB and provided by Boulting Group Ltd. The main function of this MCC is to control and monitor all the Jenbacher CHPs (new and existing units) and new ancillary plant and equipment associated with the new Jenbacher 4 Series CHPs. Ancillary plant includes one biogas dehumidifier, 3 (No.) Donkin V50 dual stage gas boosters, a siloxane removal filter, 2 (No.) Grundfos hot water circulation pumps, an engine lubrication oil storage and transfer system and associated controls and instrumentation.

The new HV switch panel contains circuit breakers to enable the CHPs to synchronise with the mains power system and to provide essential safety functions, as well as circuit breakers to feed power to the existing power network. These devices may also be tripped in the event that the synchronising circuit breakers fail to open in the event of a fault. The switch panel also contains surge arrestors for the new Jenbacher units. The panel is connected via cables to circuit breakers previously used to connect the decommissioned CHP units to the main 11kV switchboard. In order to ensure the existing HV circuit breakers were suitable for their new duty, the current transformers were replaced and protection settings updated.

A new combined earthing and lightning protection system comprising buried copper earth tape around all plant and structures was installed to reduce touch voltages to acceptable levels under fault conditions. The earthing system is also bonded to the steel reinforcing in concrete bases and to the CHP containers.

The interfaces between the CHPs and associated plant are complex both in terms of hardware (e.g. cabling) and software (control). As well as the connections between the CHP Interface MCC and each CHP, each CHP also has connections to the HV switch panel to open and close the circuit breakers to control the connection of power to the site, electricity metering connections to allow the recovery of revenue, gas metering connections to allow the remote analysis of gas usage, connections to control the filling and emptying of lubricating oil, and connections to a WAN for remote access to monitor CHP performance.

Mechanical installation

In order to meet the gas quality required for the efficient operation of the new Jenbacher CHPs a gas train comprising dehumidification plant, gas compressors and siloxane removal filter were procured and installed under MMB's contract.

The raw biogas produced by the sites 16 (No.) digesters is completely saturated resulting in 100% relative humidity at design temperatures. The presence of water in the biogas has a detrimental effect on the siloxane filter media and reduces the efficiency of gas combustion in the CHP engines. A duty dehumidification plant, supplied by APROVIS Energy Systems GmbH, was therefore required to reduce the relative humidity of the biogas, thus increasing the efficiency of the CHPs and also prolonging their operational life due to the increased performance of the siloxane filter.

Duty biogas compressors, supplied by Howden Group Limited, were designed and installed downstream of the dehumidification plant in order to serve a double purpose; firstly to increase the delivery pressure of the biogas to the CHP engines and secondly, to further reduce the relative humidity of the gas due to the temperature rise across the dual stage compressors. This has removed the need for

a gas re-heater post-dehumidification, resulting in an approximate £30k OPEX saving per year.

The siloxane removal plant, supplied by PpTek Limited, was necessary to remove the volatile organic compounds (VOCs) including organic silicon, known as siloxane when in its gaseous form, that are present in wastewater. When heated in the engine combustion chamber siloxanes form solid deposits of silicon dioxide which can cause detrimental, abrasive wear to the engine and contaminates the engine lubrication oil.

The siloxane removal filter was supplied as a single duty/standby unit, complete with an auto-regeneration system with exhaust gases dispersed through a fan assisted virtual air stack.

Water in the biogas can inhibit the filter media and reduce performance due to the deposition of salts following regeneration. The upstream dehumidification plant is designed to prolong the life of the filter media by reducing the relative humidity of the biogas.

Both clean and waste engine lubrication oil tanks, supplied by Clarke Energy, were provided for the 3 (No.) new CHPs. A delivery pump local control panel was installed by MMB's electrical subcontractor Lloyd Morris Electrical Ltd to control oil delivery to the CHPs.

To collect the 4.2MW of thermal energy from the new CHPs and deliver it back into the existing system, 2 (No.) new duty/standby process water circulation pumps, supplied by Grundfos Pumps, were installed and commissioned to maintain a 51l/s flow through the new system.

Civil works

All civil works were designed and constructed by MMB including CHP and ancillary equipment foundations, condensate and surface water drainage, footpaths, vehicle hardstands and service main diversions. The engine lubrication oil delivery and collection area was segregated from the site drainage in the area and passed through a forecourt separator before being pumped to the head of the works.

Programme and budget

The £4.6m capital scheme was designed, installed and commissioned within the 12 month target programme and project budget. MMB began outline and detailed design work on the scheme in April 2013 with construction beginning on site in August 2013 to accommodate the delivery of the first CHP in November of the same year. The further 2 (No.) CHPs and all ancillary plant and equipment were delivered to site during December 2013 and were successfully commissioned during April 2014.

The challenging target programme required extensive collaboration and effective communication between MMB and STWL with assistance from our corresponding supply chains.

Use of building information modelling (BIM)

The advantages of BIM as a collaborative tool was evidenced by the ability of MMB to agree a fully-detailed design sign off with STWL at an early stage. By providing a complete virtual tour of the proposed installation for project stakeholders, acceptance of the proposed design was unanimous at the first attempt. Communication between design and build within MMB also realised increased efficiencies through the use of BIM, allowing a single, complete design, containing all construction information to be issued.

Commissioning

To connect the new LV power, process water and biogas supplies, numerous shutdowns of the entire generating station were anticipated. However, during January 2014, as a result of meticulous design, planning, coordination and cooperation between MMB, the supply chain and STWL site operations and generating station staff,

a single, six hour shutdown of the entire generating station was required to make the biogas connection. Through the extensive planning and efficient implementation of the operation, minimal impact to the environment and existing site processes was realised.

By coordinating the low voltage and process water connections to take place together during a separate, partial shut-down of the generating station, impact on the site was further reduced. By electrically isolating only a part of the generating station, a reduced volume of gas could still be produced and burnt through the use of three existing CHPs and flare stack.

Works to connect the process water were completed safely ahead of schedule by MMB's mechanical installation subcontractor Franklyn Yates Engineering Ltd, further reducing the impact of the shut down on the temperature dependent site processes.

CHP installation complete and commissioning underway
Courtesy of MMB Ltd

Installed PpTek BGAK 4000 siloxane filter - Courtesy of MMB Ltd

Three dimensional render of new CHP installation
Courtesy of Mott MacDonald Bentley Ltd

Innovations employed on scheme

A number of innovations have been employed on this scheme to increase efficiencies in design, procurement, operation and maintenance.

High efficiency Jenbacher 4 Series CHPs were specified for this scheme to deliver the operational savings previously mentioned. This required a new, custom designed container compliant with current health and safety standards to be developed between Clarke Energy Ltd, Severn Trent Water and Mott MacDonald Bentley.

Safety standards were improved by the innovative design of elevated walkways and pipe supports cantilevered from the containers. This removed uprights at ground level, increasing pedestrian access around the containers. Integrated lifting beams were also designed into the containers to safely remove CHP engine heads, turbo chargers and intercoolers for maintenance.

To maximise power output, the 6 (No.) CHPs are controlled automatically in sequence in accordance with gas availability (derived from the gas level in 16 (No.) existing floating roof digesters via the site PLC DH+ network). The CHPs are most efficient when running at high output (>95%); the control system seeks to ensure that CHPs are run at this optimal output whenever possible. The 6 (No.) CHPs may be run in any sequence, requiring complex software to determine duty selection and to run the appropriate ancillary plant items. The Interface MCC is equipped with a full SCADA system in place of an HMI; the SCADA system is configured to directly email operational staff with critical alarms and can be remotely accessed via a secure system.

The siloxane filter's on-site regeneration system removes the health, safety and environmental risks associated with the manual monthly replacement of an equivalent granular activated carbon plant. The inclusion of the filter prolongs engine life and increases the necessary engine service intervals, which in turn reduces risk to operatives as well as operational costs.

As-dug material has been reused on site to landscape the surrounding area and construct a noise insulating bund to reduce impact on STWL's neighbours. This has meant that no spoil has been disposed off site as waste.

Conclusion

MMB as principal contractor collaborated and innovated extensively on design, pricing, construction and commissioning with the client and their site operations teams, whilst utilising both client and contractor supply chains.

Communication and collaboration between MMB, their supply chain, the site operations teams and the generating station staff was crucial to achieving multiple successful shut downs of the existing generating station gas and electrical systems to facilitate critical new biogas, hot water and low voltage supply connections.

Building information modelling was used extensively as a tool for design collaboration amongst the supply chain, culminating in a high quality end product for the client. Final commissioning of the 3 (No.) engines was completed and handed over to STWL during April 2014 with contract completion scheduled for July 2014.

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