Minworth Biomethane Injection Plant

improving the efficiency of energy generation from sewage sludge by cleaning and injecting biogas into the National Grid network

by Simon Farris MEng AMIChemE

Minworth STW, located in Sutton Coldfield near Birmingham, is Severn Trent Water's largest sewage treatment works and treats the sewage sludge of 1.7 million people in the greater Birmingham area. Severn Trent Water had developed an established fleet of nine sewage gas based combined heat and power engines that utilised biogas derived from the anaerobic digestion of sewage sludge. These engines delivered 56GWh of renewable electrical energy in financial year 2013/14 which was enough to power the site and export 20GWh to the National Electricity Grid.

Malmberg biomethane upgrader (GR14XL) that removes carbon dioxide and hydrogen sulphide - Courtesy of Minworth Gas to Grid team

Project drivers

The CHP at Minworth supplies the anaerobic digestion plant and a liquor treatment plant with low-grade heat to ensure its continuous operation all year round. For most of the year the site operated at a substantial heat surplus and was forced to waste thermal energy to the atmosphere. This was both inefficient and a waste of a valuable resource. CHP production efficiency drops to 40% from 80% when heat from the engines is not being recovered.

In 2011 the Government recognised the need for providing greater amounts of renewable heat and it introduced the Renewable Heat Incentive. This scheme would financially support biogas producers to upgrade and inject biogas into the national gas network as biomethane. Injecting biomethane ensures that 97% of the energy stored in the biogas is exported from site and it can achieve much higher final conversion efficiencies when utilised in bulk elsewhere in the National Grid Gas Network.

Biomethane is identified as a flammable gas produced from organic sources that contain 97% + methane. In the case of Minworth, this would mean upgrading sewage derived biogas from 60% to 97% methane content.

Therefore it was identified that it would be more efficient and cost beneficial to upgrade and inject the biogas that was being used for exported electrical power and wasted heat.

The project focussed on a plant capable of upgrading 1,200Nmch of biogas for injection into grid. The remaining 2,800Nmch produced by the site would be used in the existing CHP engines to provide power and heat for the site all year round with minimal support from supplementary fossil fuel sources. Minworth will target producing 63GWh of renewable gas and 40GWh of renewable electricity every year.

Scope

The development of the project was undertaken by a combination of companies working on behalf of Severn Trent Water. The largest contract was undertaken by Laing O'Rourke and Imtech Process as a joint venture. This contract was for the design and construction of a plant that would be able to upgrade the biogas to a condition that would meet the standard of national gas safety regulations.

National Grid Gas had the contract to deliver the connection point from the site to the network. This project is the first in the UK to

Final Polishing tanks (medium pressure activated carbon) to prevent pass through of chemicals into the grid - Courtesy Minworth Gas to Grid team

Uniflare VOC pre-treatment unit Courtesy of Minworth Gas to Grid team

Water scrubbing columns for Malmberg biomethane upgrader Courtesy of Minworth Gas to Grid team

connect to the local transmission system on the National Grid. The connection point is also the first in the UK to utilise energy blending. It is a system that uses high flow rates in the network to minimise propane usage.

The Severn Trent project team has also been supported throughout the design and construction of the plant by CNG Services Ltd, a company at the forefront of the biomethane industry with a wealth of knowledge in all areas of this new process to the UK.

The process

Sewage gas is a difficult gas to upgrade and inject. Other plants in operation have complete control over feedstocks and trace impurities that may pass through into the gas. Sewage gas does not have this control due to the feedstock coming from a large network sewerage system. Certain compounds such as siloxane based compounds can damage combustion equipment and fragrances from cosmetic products could impact on gas odour if concentrations are too high. Occasionally harmful chemicals are found in a sewage works like mercury or arsenic. These must be kept out of the gas network to protect human health. All of these factors have driven the decisions in process selection.

Minworth is the first sewage gas installation to inject into the National Gas Grid. This has meant challenging a number of gas legislation conventions and bringing in new technology to ensure all of these chemicals are managed properly before the gas is injected into the grid.

The Plant at Minworth is composed of 4 main processing steps:

1: Pre-conditioning: Gas coming off the AD plant at Minworth is saturated as well as containing many impurities. Previous experience protecting the CHP engines from these chemicals has shown that activated carbon is one of the most reliable technologies available. Extra chemical removal, beyond the current targets, was also necessary to meet the level of siloxane removal requested by National Grid. It has been demonstrated that activated carbon works to remove these impurities (especially siloxane) much more efficiently when the gas is dry. The pre-conditioning plant was developed with chilling/reheating units and optimised carbon bed sizing to achieve the new output limits. To date, the beds have over-performed, removing siloxanes below measurable limits and there have been no issues with ingress to the grid.

2: Carbon dioxide and hydrogen sulphide removal: This is the most common step referred to in biogas upgrading, the removal of CO_2 to ensure that the product gas goes from approximately 60% CH_4 at the inlet to 97%+ CH_4 at the outlet.

At Minworth a water scrubbing technology was selected to deliver this upgrade. The water scrubber utilises the different absorption rates of CO_2 and CH_4 in water at pressures between 4 and 7 barg. The Malmberg biogas water scrubber installed at Minworth focuses on the different partial pressures when the system is operated at approximately 6 bar. At this pressure, the CO_2 readily dissolves into the water whilst the methane passes through. This process is undertaken in a large, well packed column to ensure that the gas makes adequate contact with the water and the CO_2 is almost completely removed.

Hydrogen sulphide is also extracted at this point because its absorption rate is at a lower pressure than the CO_2 and so the process automatically takes it out. The final step in this piece of plant is to dry the gas again to ensure it conforms to Gas Safety (Management) Regulations (GS(M)R) levels.

To ensure the process remains sustainable the water is then depressurised in a second column. As the pressure drops to atmospheric levels, the CO_2 is released in gaseous form and is driven off using an air stream. The water then returns to the system for reuse in the main scrubbing column. Over prolonged periods there is a small amount of build up of CO_2 in the water. This water is discharged to the sewer and back to the works inlet and is replaced with fresh water from the mains.

3: Pressurisation: Minworth is the first site to connect into the medium pressure tier of the National Gas Grid. This pressure tier typically operates at between 7 and 32 barg. At Minworth the West Midlands Local Transmission System (LTS) operates at around 17 barg. The LTS offers a gas producer advantages in terms of available capacity and reduced propane consumption through 'energy blending'.

The product gas leaving the upgrading plant is typically between 3-5 barg and so there has to be additional compression to push the biomethane into the grid. At Minworth this has been achieved through the use of a single stage compressor provided by Wartsila, based in Havant, Hampshire. These compressors are operated oil-free to prevent ingress from oil based lubricants into the gas that may disrupt the National Gas Grid.

4: Finally the gas is tested and injected through a Grid Entry Unit. The gas is tested using a gas chromatograph to show it has both the composition and physical properties to match the gas in the grid before it is injected. The gas is predominantly methane and provides a very clean alternative to Natural Gas. This testing reviews calorific value, hydrocarbon dew point, pressure, temperature, trace element (O_2 and H_2) percentages and combustibility factors. At Minworth this is all carried out in a single containerised module provided by Elster (from Melton Mowbray, Leicestershire).

If the gas CV is found to be lower than the input value from the local gas grid, propane is dosed into the gas stream to raise the CV. There is 12 tonnes of propane storage in place on site so that if the gas requires supplementing, STW have cover for 5 days. At Minworth a pioneering energy blending system has been introduced that enables us to reduce consumption of this fossil fuel.

Prior to injection into the grid, the gas is odorised with methyl mercaptan to ensure there are no issues with any of its physical components. The gas is now at a point where it is almost identical to the gas in the National Grid network.

Energy blending

Minworth is the first site in the UK to inject into the LTS tier of the gas network. One of the main reasons for this was to ensure that the injection of propane, a fossil fuel, was not required. This is achieved through direct communication and collaboration with National Grid (NG).

NG has installed a remote monitoring point (RMP) on the network just after the Minworth gas has blended into the system. This RMP utilises a PT2 infrared analyser to detect the CV of the blended gas in the network. Whilst this remains within the legal tolerance of the network, there is a signal feedback system that tells the Grid Entry Unit (GEU) and the site to inject biomethane without propane. If the gas in the main falls outside legal tolerances, the signal is sent to start propane addition up to the full value of the network. This feedback control loop allows STW to minimise the propane addition and reduce the quantity of fossil gas being used. This is the first site where this has been achieved and performance to date has been excellent, substantially reducing the need for propane utilisation.

Internal plant room for Malmberg Upgrader: compression plant for the water scrubber - Courtesy of Minworth Gas to Grid team

Removing the contaminants: showing all of the processes for trace element removal - Courtesy of Minworth Gas to Grid team

Upgrader and exhaust treatment plant by ERG (Air Pollution Control) Ltd Courtesy of Minworth Gas to Grid team

Oil free compression plant used to make the high pressure connection Courtesy of Minworth Gas to Grid team

Ensuring compliance for VOCs
Courtesy of Minworth Gas to Grid team

Upgrading Plant from Malmberg
Courtesy of Minworth Gas to Grid team

Construction programme

The contract for the process plant was awarded to LOR-I JV in June 2013 and it took 16 months to complete. Delivery focussed on an off-site package plant production process. Each of the individual suppliers prepared their plant off site and during spring/summer 2014 these components were delivered, installed, connected and commissioned.

The system has a custom built, single control philosophy that can manually start and stop the plant under a series of operational conditions.

Construction of the site has had to be mindful of its status in the greenbelt around Birmingham. Whilst the site is a wastewater treatment works there are a number of conditions that the construction programme has had to be mindful of including visual impacts and noise. The site has developed a disused area of the Minworth that was previously of no significant value.

The construction programme has been delivered to schedule and has seen minimal downtime for the existing processes. There were no accidents and no-one was made unwell during the construction programme thanks to a well managed safety culture on the site.

Summary

Through working in collaboration with the Severn Trent framework contractors, Laing O'Rourke–Imtech JV and National Grid, Severn Trent has been able to deliver a pioneering biomethane injection plant that can be taken forward across the industry and wider. The plant has optimised the use of propane injection as well as demonstrating a pathway to grid for more complex feedstocks in anaerobic digestion. The plant is now fully commissioned and is injecting to its full potential.

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