Niederndodeleben biorefinery

Photo: GETEC green energy AG

Leakage-free biogas feeding into biorefinery

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Bio energy in the form of biogas as a CO_2-neutral energy source is becoming increasingly important. An efficient form of use is direct feeding into the public natural gas grid. At the same time, the storage problem will be elegantly solved. However, before biogas can be injected, a few steps are necessary. Leakage-free and highly-available compressors are located immediately before the feeder, which constitute a crucial connection to the grid.

Fig. 1: Biomethane grid injection station

The fundamental component of both natural gas and biogas is methane. Biogas derives its name from its biological origins, in contrast to the fossil fuel natural gas. What they both have in common is that they are both becoming more attractive for the energy market in their prepared form. Preparation for raw biogas entails removing water hydrogen sulfide and carbon dioxide. Thanks to cleansing, close to 99 % methane enrichment is possible. Before feeding, adjustments are made to the calorific value of the respective natural gas grid. This is how biogas is supplied to remote consumers themselves.

More energy efficient feeding

Feeding into a public grid, however, has a very distinct physical advantage. If biogas is solely used for generating power in a block heat and power plant, then the energetic use, or the efficiency factor, is often very low. This is due to the lack of consumers for the waste heat. Up to two-thirds of the energy in biogas remains unused. Biogas replaces natural gas via feeding and offers energetic versatility for power generation, heating or even for use as a fuel.

Volume determines profitability

There are a few requirements for creating grid-compatible biomethane from corn, cereals, grass silage, sugar beer pulp, liquid manure or dried chicken manure. Huge investments are needed in order to truly work in an economical manner. The lower profitability limit lies at approximately 250 to 500 Nm³/h of biogas production. A typical biorefinery can be found in Niederndodeleben (Saxony-Anhalt). It has been operating since 2009. A second, modern facility has been operating in parallel there since 2014 with even greater availability and improved facility and control technology. 9 million euros have already been invested for the first production line, 11 million were invested once more for the second one. The facilities combined supply approx. 1,300 Nm³/h, or 96 million kWh per year in energy. The average four-person household consumes 5,000 kWh/a, that is to say the yearly energy needs of approx. 19,200 households of this size are covered with renewable, CO_2-neutral energy.

Avoiding methane slip

The top priority in overall production is avoiding methane loss for three reasons:

- Climate protection: Methane is a powerful greenhouse gas and its global warming potential is 28 times higher than that of carbon dioxide. Manufacturer guidelines are accordingly strict. Strict TA Luft (Technical Instructions on Air Quality Control) and Gas Grid Access Ordinance (GasNZV) limits apply.

- Safety: Methane is highly combustible and reacts explosively with oxygen. Therefore, any uncontrolled leaks must be prevented. For instance, the compressors before the feeders into the natural gas network are in ex-zone 1.

- Efficiency: Energetically usable is what the prepared methane becomes. It is sold to the operators of the respective public natural gas networks via contracting. This is why losses must be reduced as much as possible during production.

Different volume flows

A critical moment in production is the start-up phase, since the bacteria in the bioreactor require a certain amount of time to multiply until the microorganisms produce the desired nominal gas quantity. Once it has started, the biogas facility mostly runs as a baseload power station, since the process cannot be naturally halted easily. All of these pre-requisites create special requirements for the compressor manufacturer. To better comprehend them, the individual process steps of a biorefinery – inspired by facility parameters in Niederndodeleben – will be depicted here.

Example Niederndodeleben

In the beginning, nearby farmers supply approx. 49,000 tons of corn silage, 34,500 tons of beet

Source: Mehrer Compression

Fig. 2: Compressor plant for biomethane grid injection

pulp, and 11,500 tons of organic fertilizer per year. These 95,000 tons of renewable raw materials (renewable resource), plant by-products and organic fertilizer are mixed in fermenters until homogeneous biomass is created. The proteins, fats and carbohydrates in the plant by-products break down under hermetical sealing and at an ideal temperature of approx. 40°C (104°F). The raw biogas created during fermentation is mainly composed of methane and carbon dioxide. In this phase, the methane percentage is approx. 53 %. Yearly raw biogas volume spans approx. 18 million Nm³. The fermented substrate can be spread again onto the fields by the farmers as an organic mixed fertilizer to conclude the cycle of materials. For the aforementioned quantities of harvested silage in Niederndodeleben, this comprises approx. 72,000 tons per year.

Washing and drying gases

In the next step, washing takes place in the gas preparation facility with the aid of a pressurized water scrubber. The main goal is desulphurization and the separation of carbon dioxide (CO_2) and methane (CH_4) gases. Sulphur is present in biogas as hydrogen sulfide (H_2S). Biological, chemical, and absorptive separation processes are also possible. Pressurized water scrubber is an absorptive process, since the alkaline and acidic components in water dissolve relatively well. The washing solvent particularly bonds the carbon dioxide and hydrogen sulfide from the biogas. Pressure increases solubility, which is why the biogas is compressed. Water is sprayed from above in the 17 m high absorption column, while raw biogas is flowing in at the bottom. The water flowing into the counterflow absorbs CO_2 and H_2S. The loaded washing solvent flows into a flash tank, where it expands to atmospheric pressure, whereupon the bonded carbon dioxide is re-released and travels outside via a waste air purification plant. Minimal residual methane is flamelessly eliminated beforehand via regenerative thermal oxidation at 800 °C (1,472 °F). The washing water is cleansed in the downstream desorption column and then re-directed to the absorption column where the cycle begins anew. The washed gas is dehumidified in an absorption drier before it reaches the feed-in system as biomethane at approx. 40 °C (104 °F). Since a small amount of methane also dissolves during the process, which is freed during release, it is re-fed from the flash tank as a lean gas to the raw biogas pending at the front. The inlet volume flow during pressurized water washing in the Niederndodeleben biorefinery amounts to approx. 2,500 Nm³/h and the outlet biogas volume flow is approx. 1,300 to 1,400 Nm³/h with methane enrichment at up to 98.5 %.

For this process, the Magdeburg biorefinery uses a total of four compressors, which are each operated as a redundant pair: An initial generation at 75 kW and a volume flow of 365 to 780 Nm³/h along with a second generation at 200 kW and a volume flow of 960 to 1,987 Nm³/h.

Preparation and feed-in

Now comes the last and decisive step in the biogas feed-in facility. This is where the prepared gases are analyzed, the pressure is increased to grid conditions and, if necessary, odorization and calorific value adjustment as per the Wobbe index using propane is carried out. This is necessary so that the biogas meets the public grid operator's quality requirements as a “high gas”.

Compressor technology with no leaking gas

In this phase, the compressor technology used is given special importance. The basic requirement is a non-gas leaking machine for placement in ex-zone 1.

The reduntantly-installed compressors are equipped with a gas-tight engine crankcase, which is indispensable for leakage-free operation. A leaked gas compressor can be used in petrochemistry to prevent leaked gas. This is generally not the case for biogas facilities. A compressor system without a leaked gas compressor is advantageous from the operator's standpoint, because this eliminates one additional machine as a potential source of faults. When considering the acquisition costs, there is no difference between a leakage-free compressor and a compressor with a separate leaked gas compressor. During operation, however, there are significantly higher costs for the leaked gas variant, since maintenance, wear parts and energy are needed for an additional machine component. And that does not include the extra space requirements. When taking into consideration the total cost of ownership (TCO), a hermetically-sealed compressor for biogas operators is cheaper without having to be wary of technical shortcomings.

Mechanical sealing in lieu of shaft sealing

The new line compressors in Niederndodeleben have an engine power output of 200 kW. For this application, mechanical sealing replaces the otherwise common shaft sealing on the crankshaft. Together with the pressure-resistant crankcase, it becomes hermetically sealed to prevent gas loss.

Biogas as a CO_2-neutral energy source is becoming increasingly important.

Avoid tensile forces

The direct-coupled machine does not use a belt drive. A claw coupling, which can manage without disturbing tensile forces, is used instead. FEM examinations have shown that having only one load, torque, on the crankshaft has an economical effect on its longevity. The belt drive provides a double load due to bending and torsion movements. The belts can never be equally tensioned and also differ in size. This produces vibration forces that affect the drive system. After all, the shaft still has a power requirement of approx. 45 to 150 kW. Such belt vibrations do not occur in direct drive. Furthermore, the clutch bell, which serves as an enclosure for the direct drive, can be designed in a more stable manner than the belt drive's enclosure. This is generally used for contact protection, which in turn also tends to resonate again. In conclusion, a coupled machine exhibits significantly reduced vibration, which is why this kind of drive train was preferred.

RPM-regulated compressors

Due to vibrations in the volume flow, particularly in the start-up phase, the compressors are RPM-regulated. The excess pressure ranges from 4.5 bars to 7 bars of overpressure. End pressure bandwidth represents a specialty. It lies between 11 and 26 bars absolute. In Niederndodeleben, natural gas operators work with a maximum of PN 25, which is why the compressor was designed for 26 bars absolute. Downward pressure fluctuations are due to the year's seasons. For instance, grid extraction is significantly higher during the winter heating season than in summer. The pre-defined standard volumetric flow is at 1,470 Nm³/h, whereas approx. 1,987 Nm³/h would be possible with the compressors in use, therefore ensuring that any higher future volume flow would not be impeded in any way.

Temperature control with chiller

The specification for the outlet temperature at the feed-in point was preset to a max. of 40 °C (104 °F). The cooling systems themselves must be self-sufficient with regards to cooling technology, since no on-site coolant can be provided. The parameters for the emerging ambient temperature at the compressor installation site have been specified at 5 °C to 40 °C (41 °F to 104 °F). At a maximum ambient temperature of 40 °C (104 °F) and an equivalent outlet temperature, the cooler size would be infinite and technically unfeasible. This requirement was met using a cold water unit, a water chiller. A water/ethylene glycol mixture circulating in it cools down the existing gas intermediate and afterstage coolers to an adjustable 20 °C (68 °F). This creates a sufficient temperature delta. The cold water unit is located outdoors outside of the ex-area and is also performance-controlled.

Chiller vs. water re-cooling plant

For this type of cooling, lower coolant temperatures can be made available than in water re-cooling plants, which are limited by ambient temperatures, because they can only achieve a ΔT of approx. 15 °K to 20 °K. Therefore, the gas temperature would be approximately 55 °C to 60 °C (131 °F to 140 °F) at a water re-cooling plant with an ambient temperature of 40 °C, which in the present case would be too high for grid feed-in. This design makes it necessary to cool down the afterstage cooler with a cold water unit as well in order to not exceed the 40 °C (104 °F) limit. Therefore, two cooling circuits would have to be operated with the corresponding detriments in error rate and costs. A simple chiller solution can easily regulate the ambient temperature to 20 °C (68 °F) with an outside air temperature of 40 °C (104 °F), which results in a gas outlet temperature of 30 °C (86 °F) at the afterstage cooler. A comfortable reserve of 10 °C (50 °F) is additionally ensured.

Bypass brings necessary flexibility

Equipping a bypass is indispensable for the compressors in a biogas facility's gas pressure regulation and measurement system. Gas production during anaerobic fermentation is determined by bacteria and is subject to natural fluctuations. Of course, an effort is naturally made to produce gas as consistently as possible by means of optimum conditions in the fermenters, which already exists for the most part in a broken-in facility. However, the gas quantities are significantly lower when starting up a facility. Nevertheless, the compressors must make do with the low quantity. Without regulation, it would simply drain the upstream cleansing stage dry. A bypass control valve has been installed to prevent this. At Niederndodeleben, the bypass begins its regulation process when the volume flow falls below 970 Nm³/h. The RPM-regulated compressor system is designed for a minimum volume flow between this lower value and 1,230 Nm³/h. Any lower and the regulated bypass valve directs a portion of the blow from the pressure side back to the suction side. The volume flow is relaxed once more and flows through the bypass until the regulation unit detects that normal values have been reached again. From an energy standpoint, the recirculation via bypass is not exactly ideal, but this function is nevertheless indispensable for a biogas system. With this simple and quick bypass valve solution for capturing decreasing suction pressure, additional expenditures on systems and undesired, frequent compressor start-up and shutdown are avoided. The regulation unit allows for compression of almost 0 to 100 % of generated gas, thereby offering maximum flexibility.

High compressor availability indispensable

Just as it is difficult to simply start bacterial gas production, it is also difficult to shut it down. Once the fermenting process is underway, the compressor must consistently and reliably transport the gas produced, and thus be available as well. To ensure this, compressors are redundantly laid out and operated on an alternating basis. However, should a breakdown still occur, then the excess gas must now be flared. Methane, as a greenhouse gas, must not be released into the atmosphere in an uncontrolled manner according to the Technical Instructions (TA). The maximum value is at 50 mg/Nm³. Since March 2013, the Gas Grid Ordinance (GasNZV) generally dictates that total methane gas slippage from a biogas plant must not exceed 0.2 %. High compressor availability prevents this, and using proven technology results in solid execution with sufficient reserves, coupled with quick and versatile service.

Reasons for planned interruptions include preventative replacement of compressor gaskets, which are mainly made of a PTFE alloy. The recommendation for dry-running compressors with crosshead guide and spacer is a maintenance interval of approx. 8,000 operating hours for the gas and oil compression seal fitting in the lantern. The same applies to piston and packing rings.

Two-stage compressor

In order to bring up the biogas that arrives at a pressure of 4.5 to 7 absolute bars to PN 25 required by public grids, a two-stage compressor is used. As a basic principle, the compression ratio of approx. 1:5 must not be exceeded in one stage. At the second stage, the V-shaped compressor block is significantly more efficient and the resulting forces are less extreme, which has a positive effect on service life and consequently, availability. The cylinder units, cylinder cover and the engine crankcase are made of ductile casting. This cast iron with graphite cast is recommended by compressor standard DIN EN 1012-1 over gray cast iron due to its improved toughness.

High availability guaranteed

All in all, the numerous reserves, with their construction, the use of high-quality materials, constructive measures for longevity, and well thought-out design with a matching maintenance offering, enable availability exceeding 97 %. Ideally, facility builders, upon request, receive a complete functional unit with precisely matched components, such as a compressor system that is equipped with all the required monitoring systems and the appropriate control unit in accordance with the plug & play principle. In this context, it is advantageous when a manufacturer can help himself using a modular system. This makes even extremely short delivery times possible. Short delivery times for the most part is very important to biogas facility operators, since such projects are often eligible. A time frame of nine months was initially available for a required facility expansion in Niederndodeleben, which was then suddenly shortened to five months. Thanks to this modular system, the right compressor block with the corresponding piston diameter, cooling packages and standardized periphery components such as a suction filter, base plate etc. could quickly be selected from finished modules in accordance with requirements. The time from inquiry to tender up to ordering was just one week. Delivery of the matching control unit for the feed-in unit including design, construction, testing, and programming was then fully completed in a timely manner in Niederndodeleben by the compressor manufacturer.

Due to the fact that the compressor system was flexibly designed with a standalone cold water unit for cooling, it offers the advantage of ideal control. Along with it comes controlling and securing the oil and cooling water pump, the cold water unit along with controlling the start-up relief unit and the bypass and cooling water regulation valves. Furthermore, the motor protection unit for the oil pump, cold water pump and the frequency converter, along with the thermistors and PTC thermistors, are monitored. Self-sufficient control cabinets are used for the compressor aggregate in order to also eliminate control unit redundancy. Data transmission is performed via a profibus connection directly to the biogas facility's control room.

Bioraffinerie Magdeburg GmbH supports this philosophy of longevity as an operator in Niederndodeleben and uses compressor systems by the same manufacturer both for preparing and for feeding. Therefore, all services related to compressors are provided under one roof. Lastly, operators will devote their attention to biogas creation. The required compressor technology should ideally and continuously perform their task in the background without interruptions.

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