Case story

Multi-biofuel district heating plant parallels 2022 emission targets, and delivers world-class 125% fuel utilisation performance

The future is now

The world-class 30 MW multi-biofuel plant in Hjørring, northern Jutland, Denmark achieves exceptionally low emission levels, and at the same time is one of the most efficient plants of its kind in the world.

Its competitive status as one of the most internationally efficient biofuel plants ever built is achieved by high demands placed on all equipment. These demands include maximal implementation of the newest IE4 synchronous reluctance (SynRM) motor technology, driving the numerous pumps and fans throughout the plant. Performance of each SynRM motor is enabled by Danfoss frequency converters.

The plant has the capacity to drive a future geothermic plant on the same site.

Despite heavy investment in new technologies, the plant has a payback period of only seven years. The result for the consumer is a planned reduction of heating rates by 5.5% for the coming financial year, 2014-2015.

2 years payback on IE4 SynRM motors by comparison with traditional IE2 motors operating at partial load.
Investment 16 M EUR
2 years payback on IE4 SynRM motors operating at partial load
7 years payback on entire new plant

Visionary aims
The goals set by Operations Manager Niels-Peter Heje at tender phase in 2011 specified the newest technologies:

1. Flexible fuel utilisation
   The primary fuel is wood chips, readily available in the local area. However, the boiler must be able to burn many different non-explosive fuels such as straw, tree roots, or tree trunks in the form of wood chips.

   “It’s a major economic advantage for us that the plant can use all types of biofuels”, explains director Per Sorensen. “We have a surplus of wood chips in the local area, so we also save on transportation costs because fuel is so close. Furthermore, it’s an advantage in CO₂ accounting”.

   To achieve multi-fuel operation, the plant tolerates a range of 35 – 55% moisture in the fuel. The optimum is 45%. Therefore if the fuel is too wet, the combustion air is preheated. If it’s too dry, the fuel is dampened by spraying with water. Water spraying is one of the several novel technologies used in this plant. The alternative is energy-costly flue gas recirculation.

2. Vertical boiler for optimal efficiency.

3. An electrostatic precipitator, instead of traditional multicyclones, removes particles from flue gas.

I actually think it would be difficult to achieve higher efficiency by investing more.

Niels-Peter Heje
Operations Manager
Hjørring District Heating A.m.b.a.
4. Synchronous reluctance (SynRM) motors and IE4 induction (IM) motors

All motors over 0.75 kW were specified as synchronous reluctance type (SynRM), 1500 RPM 4 pole motors, rated IE3 – or IE4 if available. Niels-Peter prefers SynRM over permanent magnet (PM) motors, due to PM being difficult and expensive to repair. The construction of the SynRM motor is very simple by comparison, and he therefore expects lower maintenance, and greater motor uptime.

SynRM motors have superior efficiency over IM motors. For ratings above 75 kW, IE4 SynRM surpasses IE4 IM for partial speed and load efficiency performance. For ratings below 75 kW, IM motors only meet IE3. SynRM losses are substantially lower for partial load – this is where SynRM has a distinct advantage over IM motors.

At the time of ordering in April 2013, the project paid a 20% higher price to obtain IE4 motor rating, by comparison with IE3. This is no longer the case. Prices are decreasing, and in Denmark an IE4 SynRM motor is now available for the same price as IM motors rated IE3.

5. Radial flow pumps, no inline pumps.

6. High efficiency ventilation fans.

7. Transformer located closer to plant to minimise cable losses.

8. ABB 800 XA control system, set up for PROFIBUS communication to frequency converters, control valves and instrumentation. An OPC system for communication with the cranes, absorber and emergency generator. Operators control the plant using iPads, a new solution for district heating, although already well-known in other fields.

Outstanding performance parameters

The absorber enables optimum energy utilisation

- The absorber heat pump cools flue gas down to a record low 9.5°C, far exceeding the initial target of 12°C. The low temperature expresses the extremely high utilisation of energy transferred from the boiler output. The absorber consumes extra power compared to a traditional biofuel plant without absorber, around 1 kW electricity for 20 kW extra heat. However, due to the use of modern IE4 motors, energy consumption is still competitive with a traditional biofuel plant.

- The entire power consumption of the Hjørring plant, including district heating pumps, is 12 kW per 1 MW heat produced. Traditional power ratio for a boiler alone is 10 kW per 1 MW heat produced.

Flue gas emission levels are extraordinarily low

- Levels of gas and dust emission are a fraction of the current permissible limits, and parallel the planned compliance levels for the year 2022. See table below.

<table>
<thead>
<tr>
<th>Emission type</th>
<th>Unit</th>
<th>Measured emission level at full load, April 2014</th>
<th>Maximum permissible emission limit, Denmark 2014</th>
<th>Probable maximum permissible emission limit, Denmark 2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>mg/Nm³</td>
<td>17</td>
<td>625</td>
<td>–*</td>
</tr>
<tr>
<td>NOx (NO2)</td>
<td>mg/Nm³</td>
<td>230</td>
<td>300</td>
<td>220</td>
</tr>
<tr>
<td>Dust</td>
<td>mg/Nm³</td>
<td>4.4</td>
<td>100</td>
<td>14</td>
</tr>
<tr>
<td>O₂ dry</td>
<td>%</td>
<td>7.37</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

*In 2022 focus will be on NOx emissions, and there will be no CO requirement

A total of 18 Danfoss VLT® AutomationDrive FC 302 frequency converters are installed at Hjørring District Heating plant. All frequency converters are installed with PROFIBUS and 24 V DC backup options:

<table>
<thead>
<tr>
<th>Application</th>
<th>Size</th>
<th>No. of FC 302</th>
<th>Efficiency class and motor type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler pumps</td>
<td>55 kW</td>
<td>3</td>
<td>IE4 SynRM motor</td>
</tr>
<tr>
<td>Absorber pump</td>
<td>45 kW</td>
<td>1</td>
<td>IE4 SynRM motor</td>
</tr>
<tr>
<td>Distribution network pump</td>
<td>37 kW</td>
<td>1</td>
<td>IE4 SynRM motor</td>
</tr>
<tr>
<td>Primary combustion air</td>
<td>90 kW</td>
<td>2</td>
<td>IE4 IM motor</td>
</tr>
<tr>
<td>Secondary combustion air</td>
<td>22 kW</td>
<td>1</td>
<td>IE4 SynRM motor</td>
</tr>
<tr>
<td>Quench pump</td>
<td>55 kW</td>
<td>1</td>
<td>IE4 SynRM motor</td>
</tr>
<tr>
<td>Condensate pumps for scrubbers</td>
<td>11 kW</td>
<td>1</td>
<td>IE4 SynRM motor</td>
</tr>
<tr>
<td>Flue gas fan</td>
<td>75 kW</td>
<td>1</td>
<td>IE4 IM motor</td>
</tr>
<tr>
<td>Fuel sorting</td>
<td>55 kW</td>
<td>1</td>
<td>IE3 IM motor</td>
</tr>
<tr>
<td>Fuel transport conveyor</td>
<td>132 kW</td>
<td>1</td>
<td>IE4 IM motor</td>
</tr>
<tr>
<td>Push feeder pump</td>
<td>7.5 kW</td>
<td>1</td>
<td>IE3 IM motor</td>
</tr>
<tr>
<td>Water injection boiler</td>
<td>1.1 kW</td>
<td>1</td>
<td>IE3 IM motor</td>
</tr>
</tbody>
</table>

Control parameters

- Efficiency (kW required for each MW produced)
- Fuel moisture content
- Volume of fuel

Target: 125% fuel utilisation
Design based on maximum 55% moisture content in fuel
SynRM motor compatibility now standard
As a dedicated frequency converter supplier, Danfoss is committed to manufacturing frequency converters compatible with all motor types.

Software development is always ongoing, to include algorithms to comply with the emerging motor types. In this case, the control algorithm was customized to the SynRM motors at Hjørring District Heating.

Danfoss makes some great products, and has been more cooperative and easier to work with than some of the alternative suppliers.

Niels-Peter Heje

Danfoss laboratories tested two motors, a 55 kW and a 22 kW, to prove SynRM compatibility and confirm IE4 efficiency levels.

Triggered by the development performed for this project, SynRM compatibility is now implemented as a standard feature. During commissioning, the electrician sets four motor parameters: current, RPM, frequency and torque, and enables the new automatic motor adaptation (AMA). The AMA for the SynRM motor takes 2.7 seconds, measuring the remaining required motor parameters for optimal performance and energy efficiency.

Danfoss solution
The project chose a Danfoss customised frequency converter development solution over an off-the-shelf drive-motor package from a competing supplier.

The customised solution providing SynRM compatibility is now available as standard for VLT® AutomationDrive, VLT® AQUA Drive and VLT® HVAC Drive.

Some of the reasons:
- Danfoss offered extensive application support.
- Danfoss frequency converters are compatible with all the different motor types installed in the plant.
- Hjørring District Heating already had long experience using Danfoss frequency converters.

The contractor Weiss is convinced this is the right solution and that the result is the ultimate multi-biofuel plant.

Gorm Gade Knudsen from Weiss explains, "We like Danfoss products and were not hesitant about committing to a development process. At the beginning of the project, it was quite difficult to find an IE4 motor. However nowadays, it’s already realistic to specify IE4 motors."

Based on required performance, Danfoss dimensioned the frequency converters to match the specified motors. Each frequency converter was selected for the individual load and application – pump or fan.

Weiss A/S
WEISS A/S performs project management, design, and installation of combustion plants for biofuels.

The scale of plants ranges from 1000 kW to 30 MW, with a customer base throughout Europe.

Weiss supplies its biofuel combustion solutions primarily to process industries and district heating plants. In district heating, Weiss supplies turnkey automated solutions adapted for specific requirements and conditions.

www.weiss2energy.eu

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