SMART POWER GENERATION FOR A CHANGING WORLD

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Denmark has taken a proactive role in adapting to the changing needs of the energy market. The rest of Europe can learn from this example.

“Power for a changing world” was a well known marketing slogan used by Wärtsilä Power Plants in the early 90’s. Today the slogan is even more appropriate, especially in Europe, with new renewable power generation, such as wind, solar, etc., becoming a strong part of the energy market.

The notable impact of renewable production changes many operational set-ups, and poses some totally new challenges for the energy industry. At the same time, the European Commission and Parliament have set, and will set forth, energy strategies up to 2020 and 2050 that, in addition to the use of renewable energy, focus very much also on carbon free, environmentally friendly power generation, and on the efficient
utilisation of primary fuels. This will involve a major restructuring of the conservative European energy industry and market. The work around these EU strategies aims also to give a well defined frame, with harmonised common rules and regulations for the industry to be equally applied in all member states, thus providing the basis for investments and healthy growth in the industry. In order to fulfil these strategies, new innovative solutions and flexible multipurpose plants are needed in a transparent, free-trade market with, to a large extent, distributed energy production.

This article illustrates on how the Danish company Skagen Varmeværk manages its operations in a modern liberalised Danish energy market. Denmark is acknowledged as being a frontrunner in forming its own energy laws, and at an early stage adopted very liberalized rules and regulations for its energy industry. Today, the country manages well, scoring very high marks for its amount of installed renewable and wind production, as well as for its very efficient CHP (combined heat & power) electricity production, with plants distributed evenly throughout the entire country. Skagen Varmeværk is a typical Danish district heating company, with its heat and power production based on a large extent on a Wärtsilä gas engine plant using three Wärtsilä 28SG generating sets.

District Heating in Denmark

The very first district heating system in Denmark was installed in the city of Frederiksberg in the early 1900s. This lead was gradually followed by other cities across the country, and Denmark has more than 500 district heating plants. More than half of Denmark’s energy consumption for residential heating is generated by those district heating plants, including Skagen Varmeværk which was founded in 1963.

All Danish district heating plants are governed by a district heating law that reflects the present energy policy of the Danish parliament. These regulations offer incentives for energy efficiency and, rather importantly, ensure that the treasury department collects all the agreed energy taxes. The law also states that district heating companies are not allowed to profit from heat deliveries to its members.

Skagen Varmeværk began operations in 1964 with 535 co-operative society members. The district heat was generated by a boiler plant able to operate on fossil and bio oils. In 1979, by which time the number of consumers had grown to 1050, the municipality of Skagen commissioned a waste incineration plant that was connected to the district heating system. Fiskernes Fiskeindustri, a private company, started the delivery of waste process heat to the district heating system in 1982.

Skagen Varmeværk was connected to the national gas grid system in 1988, where a new boiler station operating on natural gas was commissioned. Precisely ten years later in 1998 it was time to commission the fully automatic combined heat and power station equipped with three Wärtsilä 28SG gas engines.

The plant was designed for automatic mode enabling unattended operation outside normal working hours, when the command for starting and stopping the plant is shifted to the dispatch centre.

The facility, heat sources and equipment comprise the following:

<table>
<thead>
<tr>
<th>3 x Wärtsilä 28 SG</th>
<th>3 x 4.6 MW_electric / 19.4 MW_thermal</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 x Gas hot water boiler</td>
<td>46 MW_thermal</td>
</tr>
<tr>
<td>1 x Electrical hot water boiler</td>
<td>11 MW_thermal</td>
</tr>
<tr>
<td>Heat import from the waste Incineration plant</td>
<td>max. 6 MW_thermal</td>
</tr>
<tr>
<td>Heat import from the neighbouring industrial plant</td>
<td>max. 6 MW_thermal</td>
</tr>
<tr>
<td>Heat storage capacity/ Hot water accumulator</td>
<td>250 MW_thermal</td>
</tr>
</tbody>
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Skagen Varmeværk today

The company is responsible for operating district heating for the town of Skagen, the most northern town in Jutland, Denmark. In winter its 8400 inhabitants enjoy a quiet life without traffic jams or crowds. However, in the summertime it is transformed into a very hectic, crowded, and popular place. This ability to adapt to the rapid changes in the surrounding environment seems also to have become part of Skagen Varmeværk’s business philosophy.

The Wärtsilä powered plant is equipped with efficient heat recoveries that reach total efficiencies of far above 90%. Even though the plant is already 15 years old, its performance remains very good compared to other modern day power plants. The engines were upgraded a few years ago to give a higher output and improved performance. The plant not only produces heat for the city and power for the distribution system operator, but also actively participates in the Danish electricity regulating and primary reserve/frequency balancing markets. To handle these simultaneous production requirements effectively, very flexible operation, short start-up and shut-down capability, as well as of course operator alertness, are essential. The plant is, therefore, equipped with hot water boilers operating on natural gas and prepared for the possible use of bio-oils and fuel oils, an electrical hot water boiler operating in parallel with the gas.
engines, and of course with heat storage or an accumulator. All these units allow very flexible and environmentally sustainable production.

In addition to its own production, a municipal waste incineration plant and a nearby industry are delivering heat to the common Skagen district heating network. The waste incineration plant is naturally run as a base load plant and provides stable year-round heat production. The heat from the industrial plant is delivered more occasionally based upon the industry’s own schedules and working hours. These two additional heat sources adequately fulfil the city’s minimum heat demand during the summer period.

Skagen Varmeværk maintains its plant in good condition and constantly develops its operations to be more efficient. Danes in general are very energy conscious and strive always to utilize the full energy content of the primary fuel for production. There are even governmental rules on how to continuously improve CHP plant operations, as well as for how consumers can save energy.

Recent investments in the Skagen plant include new absorption chillers installed after the exhaust gas economizers. These squeeze out even more heat from the gas engine exhaust gases to gain total plant efficiencies reaching even far above 100%, calculated of course on the lower heating value. Furthermore, the heat storage capacity has been drastically increased by an additional heat accumulator of 350 MWh_h to achieve even greater flexibility for the plant on the power markets. The bigger heat storage capacity between the heat production and the district heating network naturally adds more operational freedom.

Managing energy production

Skagen Varmeværk is a district heating company and delivers heat according to the demand at the lowest possible cost. The required heat production, therefore, provides the framework within which electricity can be produced, for participating in the regulating and primary reserve markets. Thus, production planning demands a good knowledge of the plant’s capabilities, as well as good forecasting of market behaviour.

All the above mentioned production units are jointly utilised in an optimal way, based upon their specific operational characteristics and upon market conditions and fluctuations. The plant operates very much on the day-ahead estimates of the heat demand, and the regulating and frequency balancing markets. Depending on the balance between these two electricity markets, the
running strategy is somewhat different and involves co-operation with the dispatch centre for the area and the other power producers. The prognosticated heat consumption is flexibly managed through the heat accumulators, and provides the framework as to how the gas engines could or should be run. The varying daily spot prices on the regulating and reserve markets have, of course, an impact on the running philosophy, and the goal is always to produce electricity when the spot prices are high. When operating in these two electricity markets, the gas engine – or Smart Power Generation (SPG) -characteristics prove to be very valuable. The primary reserve market demands fast starts and stops, and the engines can cope with that. In the regulating market, the engines are run at about 70–80 % load, where again the gas engines’ high and constant part load efficiency is valuable.

If it is not worthwhile to run the engines, the corresponding heat can be produced by the gas boiler or even with the electrical boiler, provided that the electricity spot prices and the electrical network balances are favourable. The 11 MWel electrical boiler is designed to have a large operating window, and can in that way also participate in the electricity markets as a load. The excess electricity from the renewable energy production can, therefore, also be dumped into the electrical boiler and further into the heat accumulator. Electricity production is of course closely coordinated together with the electricity operator for the district or area.

Figure 2 shows a typical production track record for the heat production during a full calendar week. The diagram shows also the spot prices on the electricity markets, the regulating and power reserve markets, heat demand and production, as
well as the level of stored heat in the heat accumulator. The engines are kept warm and prepared for an unlimited number of daily starts and stops. Normally though, as indicated in Figure 2, once or twice a day is enough. The marginal cost of the plant, in conjunction with the electricity spot prices and possible ancillary service, forms the operation profile. Electricity spot prices decrease at night and the engines are usually stopped. In this operational mode, the total yearly running hours of the engines are nowadays around 2000 hours. The engines are seldom run during weekends when the electricity spot prices are low.

From Figure 2 it can also be seen that the electrical boiler is operating mainly during the night and is then participating in both of the electricity markets. It is able to act fast as a load for getting rid of excess electricity in the grid, or to control the frequency of the grid. The heat from this boiler is fed to storage and to the DH (district heating) network.

**The impact of new European harmonised rules & regulations**

The European Energy Strategy 2020 identifies energy efficiency as one of the key priorities of the EU’s energy policy. The 20% goal for renewable power is broadly on track, while the 20% primary energy saving target is still a long way from achieving the 2020 objective. The recently agreed Energy Efficiency Directive (EED) aims to give new momentum to energy efficiency measures.

The EED is expected to recognise that the anticipated strong growth of renewable power creates a need to also include high efficiency cogeneration plants in grid stability management, and in the electrical ancillary service market. Unnecessary obstacles for accessing the grid and the ancillary service market should be removed by the member states.

Cogeneration and CHP in plants with flexible running patterns by necessity demand heat storage, which the EED highlights as an area requiring development. In situations with for instance, excess wind power, this energy could be stored for heating purposes.

Engine plants easily fulfil the “high efficiency cogeneration” criteria presented in the EED, as well as fast start up and turn down capabilities. Furthermore, compared to pure peaking plants, the annual electrical efficiency can be slightly increased in cogeneration plants due to the possibility of using the stored heat for preheating engines on standby.

The EED is now going forward within the EU, and will finally be approved in the EU Parliament. After this approval the EED goes for implementation by the EU member states. The member states are then to
apply and implement the EED, and the ideas behind it, into their own laws and regulations.

In order to fulfil the EU’s energy policy and strategies, there are a number of different rules and regulations being worked on in order to harmonise the systems and operations between member states. The harmonisation of all the different Network Codes for the power and electricity industry will provide a framework for the whole Europe. The intention is that electricity trading between member states, between transmission system operators (TSOs), and between distribution system operators, runs smoothly and fluently throughout Europe.

**Advanced energy thinking**

Skagen Varmeværk has recently invested in a new, very modern and nice office building, which naturally includes a sophisticated HVAC (heating, ventilation and air conditioning) system. The soil below the plant and office is somewhat special and can be utilised via heat pumps for both the heating and cooling of buildings, and this characteristic is utilised for the new office building as well. During the winter period and cold season, the heat in the ground is therefore “pumped up” for heating the building. This of course cools down the ground and soil, which can then be utilised for cooling down these facilities during the summer. During the hot season, the soil is therefore heated and can then be utilised for the coming autumn and winter. The soil under the office building thus acts as a small heat storage.

Denmark has realised that energy is a big consideration for industry as a whole, and for all its various activities. This attitude and very mature energy thinking is, therefore, and implemented everywhere, the push for higher and higher efficiencies is on-going. Smart Power Generation combined with district heating solution is a sensible choice for the future.
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