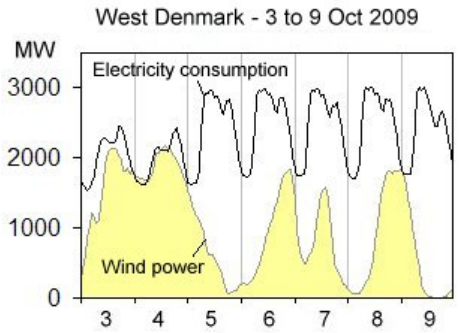
50% wind energy – Options and challenges

Co-ordinated energy systems, active participation of consumers, new communication networks and automation with distributed intelligence are some of the new exciting measures which can help Denmark to utilize twice the present amount of wind energy.

Present and future requirements for the power system

The wind varies considerably and unfortunately not at all in line with the electricity demand as demonstrated in the case from October 2009.



Electricity consumption and wind power during one week in October 2009

Doubling the wind power in Denmark will therefore make the provision of electricity in accordance with the demand more difficult. Nevertheless we assume the security of supply to be high, even in the future.

Similarly we assume that the district heating systems can be supplied with environmentally friendly heat from combined heat and power (CHP) plants and industries.

Finally we must aim at an efficient utilization of the additional wind energy. Twice the wind power on the chart will during certain periods create a surplus of electricity which should be utilized the best possible way to the benefit of environment.

Competition for Norwegian regulating services

Denmark has a small power system with strong interconnections to the neighbouring countries and excellent opportunities for trading electricity.

The Norwegian hydro power and large water storages offer good opportunities for supplying the regulating services needed in Denmark. However, it should be considered that Germany has ten times as much wind power as Denmark and ambitious extension plans for wind power. The outcome will be a large and increasing demand for regulating services and consequently increasing prices.

Germany and Denmark are trading in the same international electricity market. The competition for purchase of regulating services will be to the benefit of Norway, but it will also imply better economic prospects for regulating concepts to be developed locally in Denmark and Germany.

Denmark must remain active in the international electricity trade. In addition a development of new methods and technologies will be required aiming at the provision of regulating services from domestic sources in line with current market conditions.

Promising interaction with combined heat and power systems

Denmark has no hydro power with water storages. The hot water in the pipes and hot water storages of the district heating systems is by far the largest energy reservoir in the Danish energy systems. Therefore the CHP systems have an operational flexibility which is an important asset for the integration of additional wind power.

Paul-Frederik Bach

4 December 2009

In a recent news letter the Danish transmission system operator, Energinet.dk, has described very promising results already achieved by installation of electric heating elements for direct conversion of electricity into hot water when this is the proper choice according to the market prices.

Direct heating by electricity was a taboo for many years, but when the alternative is negative spot prices direct heating of water will be a better utilization of the wind energy. New legislation has broken with traditional thinking and made the concept profitable.

It is a decisive condition of a successful interaction that the concept includes a strong motivation for the large number of potential participants.

It will be demonstrated below how this concept can pave the way for additional wind power.

Can electricity consumption be made flexible?

So far we considered electricity demand as a dictate by the customers. The suppliers should adapt themselves to the needs of the customers.

Even this dogma must be disregarded if a large amount of wind power should be successfully integrated. In fact there are some possibilities for adapting the demand for electricity to the actual market condition.

Charging electric cars is supposed to become an essential contribution. Some even think that the batteries in electric cars might be used for supplies to the grid when the market price of electricity is high (a concept called V2G).

However, we cannot succeed by imposing restriction on the consumers. As for the CHP plants we must develop methods based on the interests of the customers. New market arrangements designed for end customers are required. Customers should have automation designed for optimizing and controlling electricity consumption of the installation concerned in order to save customers from speculation. This will require access to some market data for the moment and for hours ahead.

A considerable development effort will be required for this purpose. It is hard to estimate the magnitude of the potential. The best way forward will probably be to execute a pilot project for a selected area in order to test the viability of the idea.

Focus on security of supply

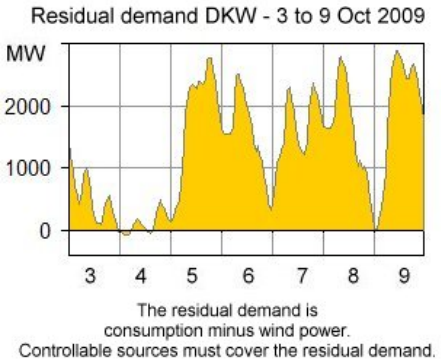
We are used to a high security of supply depending on a high readiness of reserve capacity and advanced technology.

By the introduction of decentralised generation and additional wind power new combinations might create new risks and require new measures in order to maintain the security of supply.

So far security of supply of Danish power systems was mainly based on international experience mainly collected from major disturbances and blackouts. Now Denmark is moving into a structure without precedence anywhere else. It will require careful attention and cautiousness to develop new measures without having to collect experience the hard way.

The need for regulating capacity

The electricity consumption in Denmark during the week 3rd to 9th October 2009 varied between about 1,500 MW and about 3,000 MW. Without wind power the supplier therefore must provide regulation within a 1,450 MW band during the week.

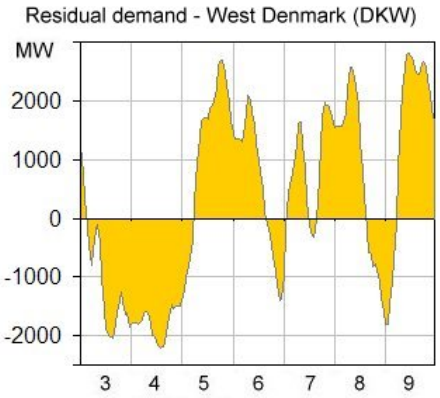


The residual demand is consumption minus wind power. Controllable sources must cover the residual demand.

However, due to wind power the controllable sources must rather be able to cover a 3,000 MW band or twice as much, as demonstrated on the chart.

The transmission system operator, Energinet.dk, must enter into agreements with suppliers who are able to guarantee that the necessary regulating capacity is available at any time.

The most important controllable sources are domestic power stations and trade across the borders.



Residual demand for the same week with twice as much wind power

In case of the double amount of wind power the residual demand would reveal the need for an even larger regulating band. About 5,000 MW of regulating capacity will be required.

The case demonstrates that the regulating band will grow nearly proportional with the maximum generation of wind power. However, it is not necessarily a problem to produce 3,000 MW during calms or export 2,000 MW during storms.

But we are supposed to meet other targets and we cannot assume that there is available capacity on the interconnectors or acceptable trading opportunities at any time.

Meeting all demands is a jigsaw puzzle

A continued high security of supply and a high operational security were among of our basic requirements. Energinet.dk has therefore issued a list of requirements for access to reserve capacities including not less than three large generating units on line at any time in each of the two Danish power systems. Three large running units imply a minimum thermal generation which we estimate at 350 MW.

Supply of heat for the district heating systems was another basic requirement. There is a limited demand for heat in October. Our estimate is 500 TJ per week for central power stations and half that amount from local CHP plants. This particular week had a rather high average level of wind.

A simple calculation on an hourly basis can demonstrate how the demands can be met.

Some people assume that waste heat can be extracted from CHP plants at no cost. This is not true. Combined heat and power production implies a considerable benefit, but neither

electricity nor heat is free of charge. Therefore a CHP plants should supply both products only when justified by a demand for both electricity and heat.

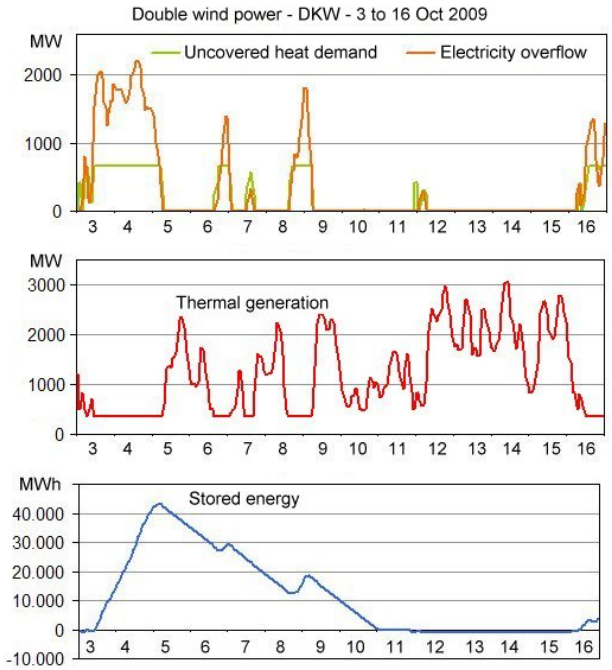
During hours with abundant wind power the thermal power stations are operated at the minimum generation mentioned above. Under such conditions the thermal units can cover only a part of the demand for heat. For the demonstration we assume that the surplus of electricity can be utilized for supplying heat or storing heat.

The calculation was based on data for West Denmark during two weeks from 3rd to 16th October 2009, but with the double amount of wind power.

The upper chart shows the good coincidence in time between unsupplied heat and surplus of electricity.

In order to stress the system we assume no exchange with neighbouring countries during the two weeks.

The thermal production of electricity will fluctuate inconveniently, but probably not much more than now. The thermal units must regulate between 350 MW and 3,000 MW. The 2,650 MW will be slightly more than half the total requirement for regulation after doubling the wind power.



700 MW of the remaining variation can be utilized for uncovered heat demand while up to 1,500 MW are assumed to be absorbed by hot water storages.

Due to the large surplus of electricity during the first weekend more than 40 GWh must be stored as hot water. The total capacity of the hot water storages connected to the district heating systems in West Denmark is unknown, but 40 GWh could be a realistic magnitude.

The case demonstrates that simple technology can add considerable flexibility to Danish power systems, even with 50% wind energy. The flexibility will be to the benefit of Danish interests in an intensified international competition for regulating services and may even imply new export opportunities.

Other sources of flexibility should be developed and implemented in line with the technological opportunities and economic conditions.

Efficient markets are the key to flexibility

Preparation for an uncertain future requires creation of alternative opportunities. Optimizing into a perfect solution is dangerous, if small changes of conditions can upset the outcome completely. This risk was demonstrated by the gambling on clean and cheap oil prior to the oil crisis in 1973.

The decentralized generation has created a large number of decision makers in the daily operation. Each of these decision makers are supposed to contribute to the optimal operation of the entire energy system. This could probably not be achieved by traditional centrally controlled load dispatch.

The electricity markets and the new communication facilities were a gift. If the market design is good enough each decision maker can be useful for the entire system by trading optimally in his own interest.

For the time being it is important that the Nordic wholesale market and the interaction with other European markets are efficient. Later a more dynamic end-user market may be needed, particularly if contributions to the system balance from charging and discharging of batteries in electric cars are wanted.

The unsolved problem

While we demonstrated that efficient coordination between electricity supply and district heating systems can create practical conditions for a reasonable domestic utilization of large amounts of wind power we have ignored an essential problem. When half the original electricity consumption is supposed to be covered by wind energy the other half must be covered by thermal power stations.

Several Danish power stations must be replaced before 2025 when the 50% target is expected to be met. But which types of power stations should replace the present generation and which sort of fuel are they supposed to use?

Most people at once doom coal due to the carbon emission. Natural gas has excellent properties, but is not carbon free either. Furthermore the amount of natural gas in the North Sea is shrinking and cannot last for the life time of a new power station.

It is an irony that the energy political development, which was started by a price increase of Arab oil in October 1973, seems to end with all of Western Europe being dependent on import of gas from states or via states, which could be as unstable as the countries supplying oil before 1973.

Waste and biomass are alternative fuels but they will probably not be able to replace the present use of coal and gas.

It was demonstrated in a previous section that new power stations must have good regulating characteristics. Out of regard for security of supply some of the new power stations should be multi fuel power plants, and their economy should not depend of a high annual utilisation.

The perfect power plant of the future has not been designed yet. A great challenge is waiting.