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System Value of Electricity Storage

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1. Introduction

In this report the value of electricity storage in Eltra's system will be evaluated. The evaluation is based on current market prices for spot power (Nord Pool's quotation, West Denmark) and real-time imbalance power in Eltra's area during the period July 1, 1999 to June 30, 2000.

The storage can be used for

- "adding value" to power in the spot market, i.e. storing inexpensive spot power and discharging expensive spot power
- reducing the demand for real-time imbalance power to compensate for miscalculation of wind power

2. Value in the Spot Market

Figure 1 illustrates the operational principle of electricity storage used for adding value to power in the spot market. When the spot price is low, energy is stored (purchased) from the spot market and subsequently discharged (sold) to the spot market when the price is high.

It is possible to set *an upper limit value* on the electricity storage by presuming that the System Operator – at the beginning of the period – knows *the spot price for the entire period* (one year: July 1, 1999 to June 30, 2000). The spot price is exogenous. In reality, it is very difficult to predict the spot price as it depends on several different factors: precipitation in Scandinavia (wet/dry year), wind (volume of wind power production), temperature, economic trends, demand, etc. as well as a number of psychological factors in the market.

The upper limit value can be determined as the solution to a linear optimisation problem which is done by using the programme GAMS (General Algebraic Modelling System).

Figure 2 shows the results in million DKK per year of the charge/discharge capacities in the range from 0 to 200 MW and the storage capacity in the range from 400 to 1,000 MWh. The efficiency of the electricity storage is 85 per cent during charge and discharge.
Figure 2 indicates that with e.g. a charge capacity of 50 MW and a total energy capacity of 1,000 MWh (20-hour charge duration) the system value is approx. DKK 5 million during the period in question (one year).

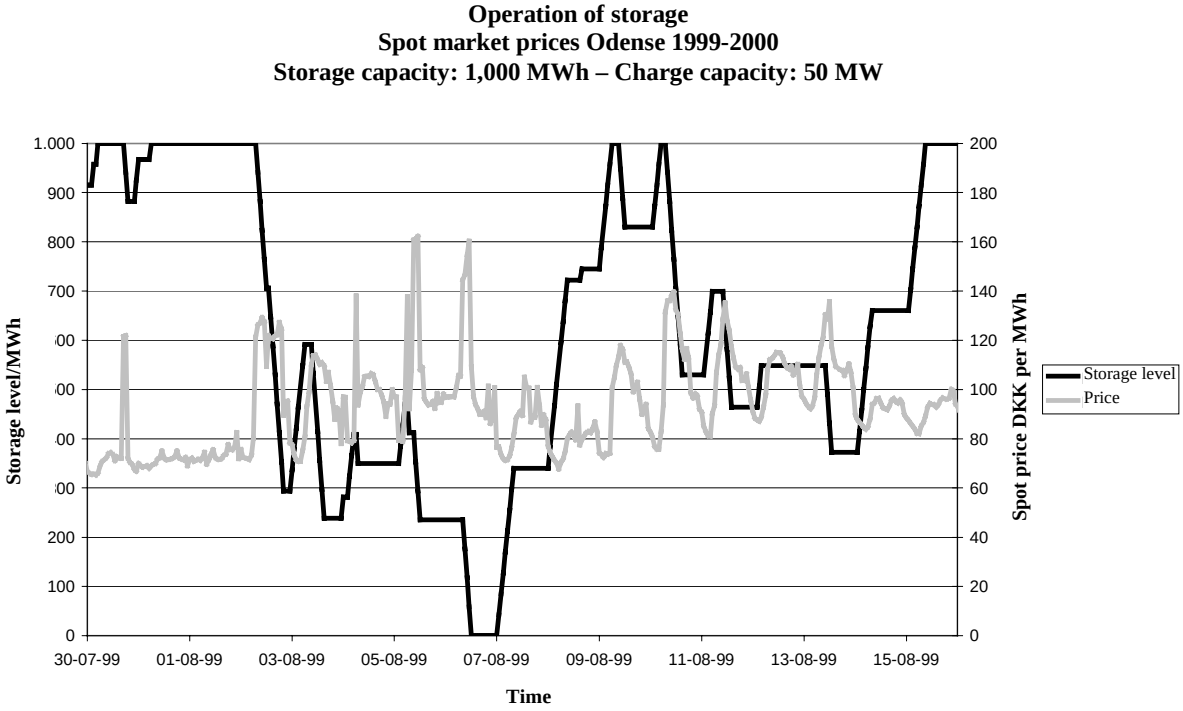

Figure 1 Operation of electricity storage compared to the spot market based on Nord Pool's spot prices for Denmark West (1999-2000)

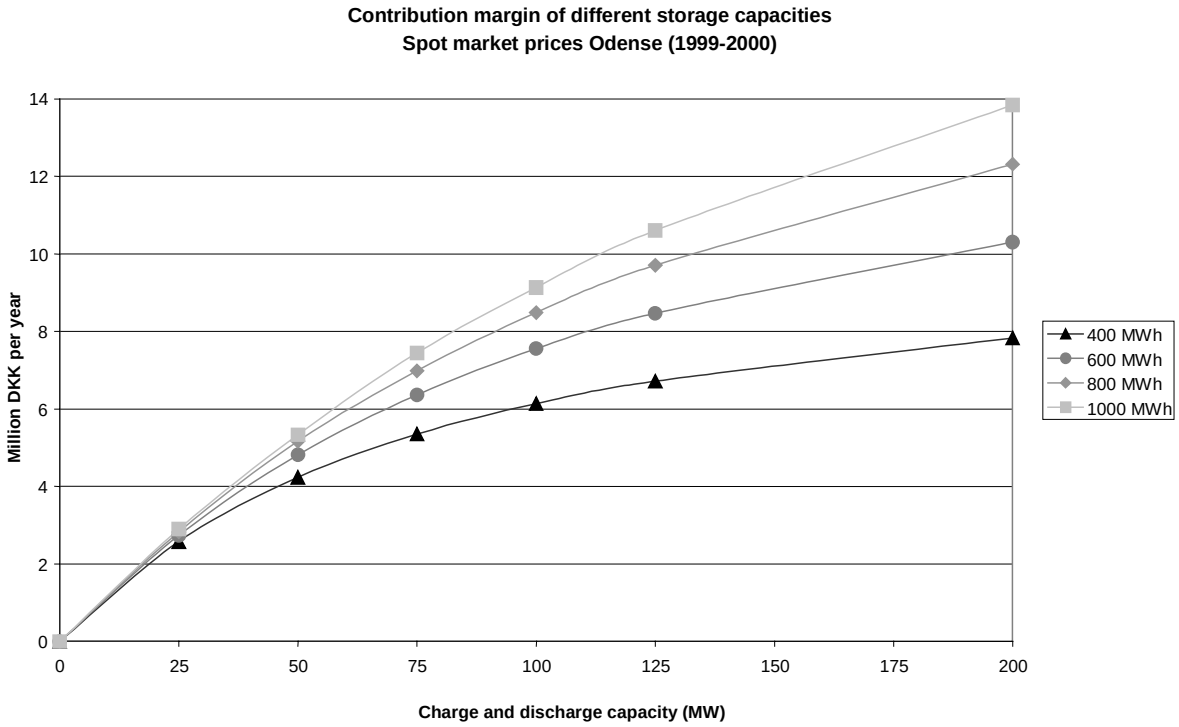

Figure 2 System value (upper value) of electricity storage in the spot market

3. Value in Real-time Imbalance Power Market

Figure 3 shows Eltra's three-month forecast for wind power, the forecast at noon on the day before the 24-hour operation period as well as the actual wind power production. The figure covers the production in one week from the end of November to the beginning of December in 1999.

If the forecast at noon on the day before the 24-hour operation period were accurate it would be possible to administer wind power on equal terms with dispatchable power in the spot market. However, as it appears from figure 3 the forecast on the day before the 24-hour operation period is far from accurate: during some hours the actual production of the week in question differs from the forecasted value of the day before with up to 800 MW.

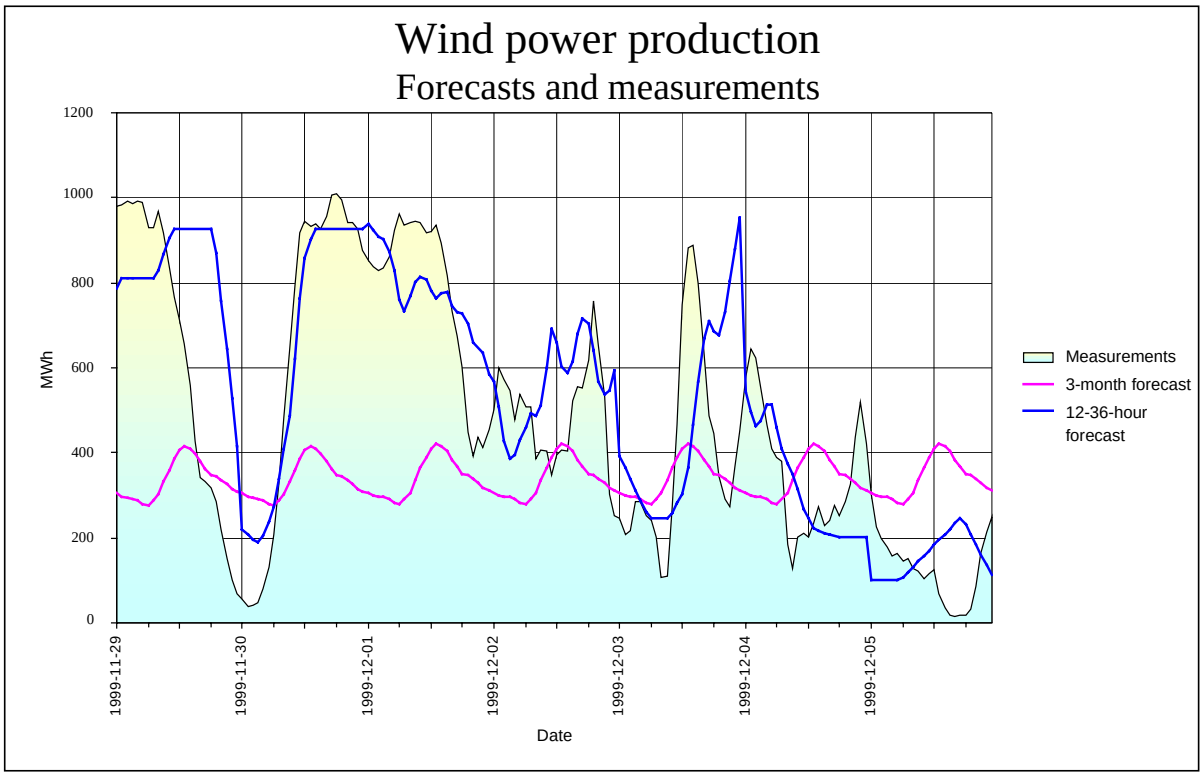

Figure 3 The wind power production (value per hour) during one week in Eltra's area compared to the forecast on the day before and the forecast three months before

Due to the unpredictability of wind power extra costs are added to wind power in the form of payment of real-time imbalance power, but with electricity storage it will be possible to reduce the need to purchase or sell real-time imbalance power: when the wind power production is lower than the forecasted production, electricity can be produced from the storage; conversely, excess wind power can be stored when the actual wind power production exceeds the forecast on the day before.

Figure 4 shows the value of electricity storage to Eltra's system during the period July 1, 1999 to June 30, 2000 (one year) with the actual real-time imbalance power prices.

As in section 2 (figure 2) values of the charge/discharge capacities in the range from 0 to 200 MW and the storage capacity in the range from 400 to 1,000 MWh have been calculated. The efficiency of the electricity storage is 85 per cent during charge and discharge. The real-time imbalance power prices were in the range from DKK 30 to 50 per MWh when upward regulation took place and DKK -80 to -50 per MWh when downward regulation took place; the prices are stated in relation to the area spot price. The calculations were done in a spreadsheet.

For example, figure 4 indicates that the value of the electricity storage – with a charge capacity of 50 MW and a total energy capacity of 1,000 MWh (20-hour charge duration) – is approx. DKK 10 million during the period in question (one year). The value represents reduced costs relating to real-time imbalance power. The total wind power production amounted to approx. 2.6 TWh and the total costs of real-time imbalance power relating to wind power (without electricity storage) totalled approx. DKK 50 million corresponding to approx. DKK 0.02 per kWh of wind power production.

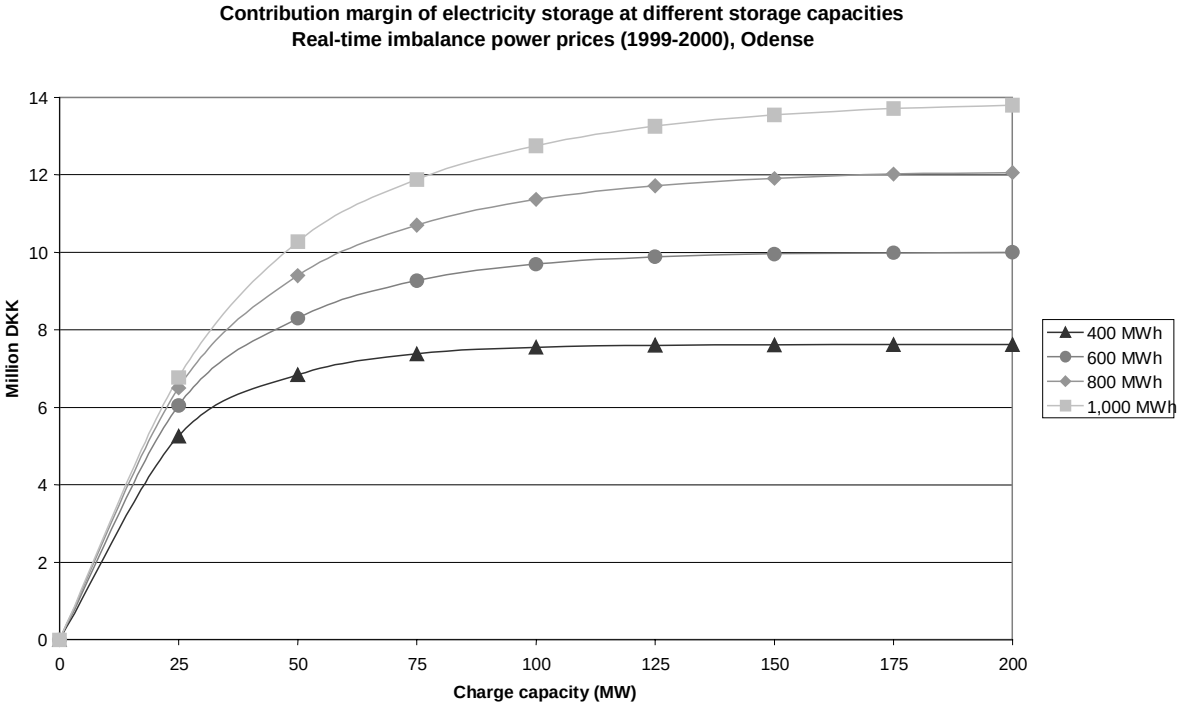

Figure 4 System value of electricity storage in the real-time imbalance power market

4. Summary

Figure 5 shows the results of the total value in the spot market and the real-time imbalance power market of the electricity storage capacities 400 MWh and 1,000 MWh, respectively.

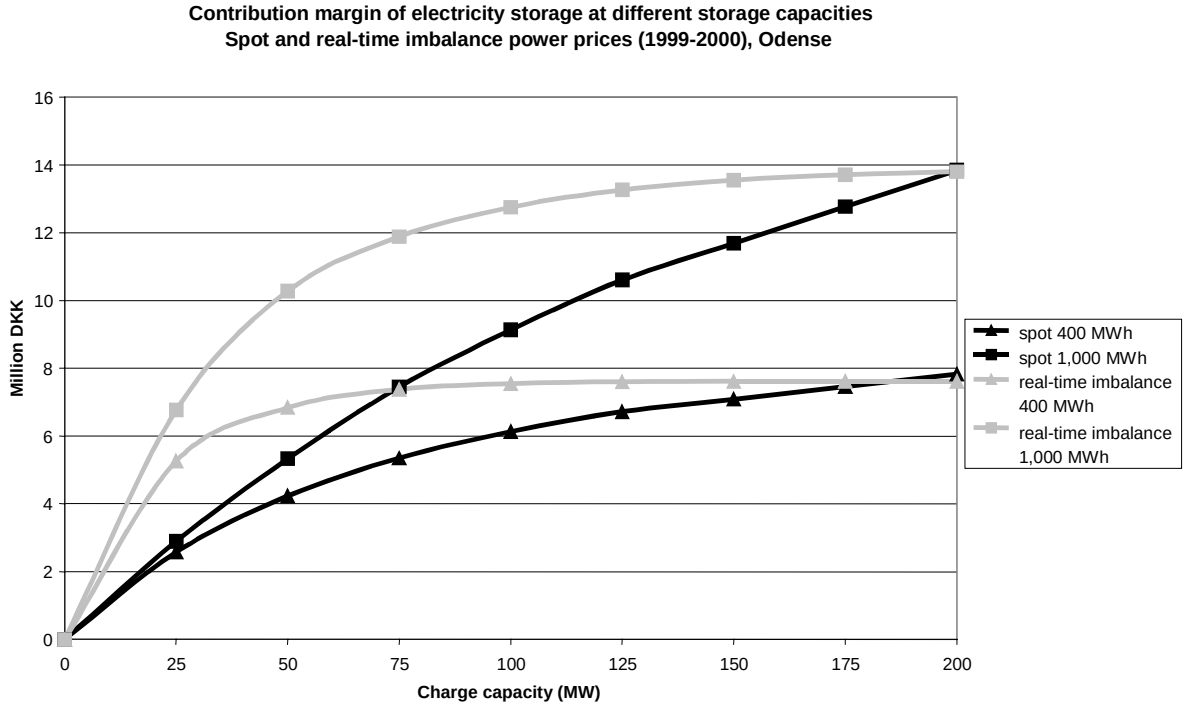

Figure 5 Comparison of electricity storage value in the spot market and real-time imbalance market, respectively (400 and 1,000 MW)

As it appears, the value of electricity storage with charge and discharge capacities lower than 200 MW is highest in the real-time imbalance market – amongst others this is caused by:

- the price structure (price and price fluctuations) in the spot and real-time imbalance power market during the period in question
- the quality of the wind power forecast at noon on the day before operation (the value of the storage in the real-time imbalance market decreases when the accuracy of the forecast increases)
- the size of installed wind power

Figure 5 shows that the curves representing the real-time imbalance market flatten compared with the curves representing the spot market when increasing charge and discharge capacity values.

When reaching a charge capacity of approx. 200 MW the curves intersect and the spot value (an upper value, see section 2) of the electricity storage exceeds the real-time imbalance power value. The reason for this is that the real-time imbalance power value reaches an upper limit when the charge capacity is sufficiently high (fixed storage capacity). This limit is governed by physical circumstances (installed wind power) and forecast uncertainty. Contrary to this, it is assumed that the spot market is immensely

large with exogenous spot prices and thus independent of the electricity storage parameters.