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Integrated energy systems and local energy markets

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Abstract

Significant benefits are connected with an increase in the flexibility of the Danish energy system. On the one hand, it is possible to benefit from trading electricity with neighbouring countries, and on the other, Denmark will be able to make better use of wind power and other types of renewable energy in the future. This paper presents the analysis of different ways of increasing flexibility in the Danish energy system by the use of local regulation mechanisms. This strategy is compared with the opposite extreme, i.e. trying to solve all balancing problems via electricity trade on the international market. The conclusion is that it is feasible for the Danish society to include the CHP plants in the balancing of fluctuating wind power. There are major advantages in equipping small CHP plants as well as the large CHP plants with heat pumps. By doing so, it will be possible to increase the share of wind power from the present 20 to 40% without causing significant problems of imbalance between electricity consumption and production. Investment in increased flexibility is in itself profitable. Furthermore, the feasibility of wind power is improved.

Keywords: Renewable energy; Feasibility studies; Electricity markets

1. Introduction

In June 2004, representatives from more than 150 countries met at the Renewable2004 conference in Bonn, Germany, and adopted a political declaration and an international action programme. The political declaration underlines the need to remove barriers for renewable energy and internalising environmental costs in energy prices. The international action programme comprises more than 150 national and international activities to support renewable energy including the Chinese goal of expanding renewable energy to 10% by 2010 and the Philippine goal of doubling renewable energy use by 2013. The countries agreed to work within a global policy network, and to take renewable energy to the meetings in the UN Committee on Sustainable Development (CSD) that will focus on energy in 2006 and 2007.

Renewable energy together with energy conservation and combined heat and power production (CHP) are essential factors for the implementation of climate change response objectives in Europe as well as in many other regions. The EU strategy is to increase the share of electricity production from Renewable energy sources (European Council, 2001) as well as from CHP (European Council, 2002). At the same time, the implementation of an internal electricity market is very important to the EU (European Council, 2003). In many EU member countries as well as in other countries around the world it is being discussed how to combine the introduction of competitive electricity markets with the implementation of ambiguous RES targets (Clark and Jensen, 2001; Duic et al., 2003; Hendriks and Blok, 1996; Hennicke, 2004; Holttinen, in press; Hvelplund, 2001; Komor and Bazilian, in press; Lund and Andersen, 2004; Lund et al., 1999; Meyer, 2003; Mitchell and Connor, 2004; Rio Gonzalez et al., in press; Skytte, 1999).

Denmark is one of the leading countries in terms of implementing the combination of CHP, energy

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conservation and renewable energy. The primary energy supply has been kept constant for more than 30 years. Today 50 per cent of Danish electricity demand is produced in CHP and approximately 20 per cent is produced as wind power. Moreover, a further expansion is intended. In March 2004 a broad coalition in the Danish parliament decided on an ambitious plan of further expansion of both onshore and offshore wind power. Consequently, the share of wind power is going to be 25 per cent within only 5 years. All the wind power is assumed to be exported and hence sold on the international electricity markets.

Meanwhile, in order to implement large-scale integration of electricity production from fluctuating renewable energy sources, the sources must be integrated with the rest of the production units in the system to make it possible for the system to secure a balance between supply and demand (Alberg Ostergaard, 2003; Duic and Graca Carvalho, 2004; Hvelplund and Lund, 1998; Lund, 2004; Lund and Ostergaard, 2000; Lund and Clark, 2002). The problem is even more complicated when RES is implemented together with CHP and energy conservation measures.

Already now, the integration of wind and CHP causes problems to the Danish electricity supply in terms of excess production in certain hours. The problems can be seen especially in the western part of Denmark where the share of small CHP plants and wind turbines is high (Lund and Münster, 2003a). In several situations the excess electricity production together with bottlenecks in the transmission lines to the neighbour countries has greatly influenced the market prices. Based on the Danish case this paper presents some possible strategies to solve the problems and to improve the possibilities of integrating more RES electricity production into the energy supply system.

The implementation of flexible regulation systems such as including the CHP units in the regulation and possible investments in heat pumps and heat storage capacity has been analysed. Such systems have been evaluated on their ability to avoid excess production in the system and on their ability to exploit trade on the international electricity market.

The feasibility of investments in flexible energy systems suitable for the large-scale integration of fluctuating electricity production from renewable energy sources has been analysed on the system ability to exploit trade on the international electricity market. The analysis methodology for the Danish electricity system involves the use of the energy system analysis computer model EnergyPLAN and a detailed assumption for the development of the Nordic market for electricity, Nord Pool.

2. The Nord Pool market

At the Nord Pool spot market in Oslo a system price for the Nordic region is calculated one day ahead using the incoming bids for selling and buying of electricity. The price is determined to provide equability between production and consumption for all hours. Economic calculations for the Danish electricity system now and in the future require an assumption for the yearly price variation for a given year. In the following it is described how this has been designed by adding a number of functions to a standard hour by hour price variation based on historical data. The assumption necessarily includes many uncertainties. Thus, the results should be interpreted qualitatively rather than quantitatively.

2.1. Standard price variation

Historical data shows that the variations in Nord Pool spot prices during a day follow the same pattern from one year to another, while the average price level does shift. Consequently, the starting point of the assumption is a standard price variation designed on the basis of actual prices during the first half of 2002 (see Fig. 1).

The period is chosen because it is recent (Nord Pool is a young organisation, still under development) and because this period is not influenced by specific circumstances, such as the situation during the second half of 2002 in which the price level rose due to lack of water in the reservoirs of the hydropower systems in Norway. The 2002 prices have been slightly adjusted to the expected prices during a "wet year" (see Section 2.2), namely 140 DKK/MWh equal to approximately 19 EUR/MWh.

2.2. Dependency on annual rainfall

The Nord Pool prices depend very much on the water content in the reservoirs of the hydrosystems in Sweden and Norway. Consequently, the assumption distinguishes between years with lots of rain (wet years), years with normal rain (normal years) and years with very little rain (dry years). Historical data show that out of 7 years, typically one is a dry year, three are wet years and three are normal years (Norsk Olie- og energidepartment, 2001). Thus a 7 year period is made up of one dry year and three wet and normal years.

The average price of the 7 year period is adjusted to the expectations of the Danish Energy Agency (Danish Energy Agency, 2003). Today the price level is dominated by severe surplus capacity. The historical price level has then in many situations been close to the short-term marginal costs not including the investment. In future, when new capacity will be needed, the price level is expected to increase to the long-term marginal costs (including investment costs of new capacity). The Danish Energy Agency expects the price level in 2010 to be 32 EUR/MWh set by the long-term marginal price of new combined cycle units in Norway, which are