WILMAR Wind Power Integration in Liberalised Electricity Markets

NEWSLETTER

Editorial

This is the first in a series of semi-annual newsletters on the research project WILMAR (Wind Power Integration in Liberalised Electricity Markets), which is supported by the European Commission under the Fifth Framework Programme (Contract No. ENK5-CT-2002-00663). The project was launched in November 2002 with an overall project duration of 36 months. The key task of the project, in which three industrial partners collaborate with several scientific institutions, is to analyse the technical and economical impacts of introducing different shares of wind power in a large electricity system where the dispatch of the power producing units is determined through trade on electricity markets. A key issue when studying wind power impacts is to give a proper representation of the stochasticity of wind power production. One of the main efforts of the project is therefore to develop a large stochastic optimisation model for the liberalised electricity systems in Denmark, Finland, Germany, Norway and Sweden with hourly time resolution. The model with data will be public and to our knowledge be the first public model of this type. The second main effort is to analyse the issue of system stability, i.e., the wind integration aspects connected to the fast (less than 10 minutes) fluctuations in the wind power production. One year of the project period has passed and three project meetings have been held. The project has started up well and the development of sub models and collection of data is in good progress. In this newsletter, the objectives, effort and expected results of the WILMAR project is presented followed by the first results regarding the design of the optimisation model. Finally, contact details for the institutions involved in Wilmar are given at the end of the newsletter.

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Subscription to newsletter

People interested in being kept up to date with the progress and results of the Wilmar project should visit the Wilmar homepage (www.wilmar.risoe.dk). Subscription to forthcoming issues of the Wilmar newsletter can be done on the Wilmar homepage: www.wilmar.risoe.dk/tilmelding_til_newsletter.htm. People who register to the newsletter will join the Wilmar dissemination group and be informed about the workshops and publications of the project.

Project Description

Objectives

A fast introduction of large amounts of intermitting renewable power production such as wind power can cause technical and economical problems of the power systems. These problems might arise due to unpredictability of wind power or due to imbalance between local power demands and intermitting power produced causing grid instabilities. The main objective of WILMAR is to investigate these problems and to develop a modelling tool (hereafter called the Planning model), which can be used to simulate alternative solutions providing a firm basis for decision-making by system operators, power producers and energy authorities.

Description of Work

The modelling and simulation efforts can be divided into two parts. One part consists of an investigation of wind integration ability of large electricity systems with substantial amounts of power trade in power pools. With the starting point in the Balmorel model (see www.balmorel.dk), an hour-by-hour stochastic optimisation model of an electricity system where the basic dispatch of the power producing units is governed by trade on a day-ahead market and a regulating power (intra-day) market is developed. This Planning model is used to investigate the technical and cost issues of integrating large amounts of wind power into the electricity system. The Planning model will cover the two power pools: Nord Pool and European Power Exchange (EEX), i.e., Germany, Denmark, Norway, Sweden and Finland. It will be tested by different end-users, e.g., systems operators and power producers, who are also expected to be users of the final Planning model.

Secondly, the issue of system stability is investigated, i.e., the wind integration aspects connected to the fast (less than 10 minutes) fluctuations in the wind power production, with the use of dedicated power system simulation tools. It includes the analysis of a number of case studies, especially selected for large-scale integration of renewable energy generation and with expected potential stability problems. The worst cases will be selected based on input from model runs with the Planning model.

Finally, the results obtained will be summarised and used to provide recommendations about the technical integration possibilities, the integration costs of wind power and the organisation of power pools.

Design of the Planning Model

Model Goals

One of the main goals in the WILMAR project is to make a model of a large liberalised electricity system covering the following countries: Denmark, Finland, Germany, Norway and Sweden**.** The purpose of the Planning model is to analyse the impacts of significant amounts of wind power in the North European electricity system. The dispatch of the generating units in the electricity system is governed by trade on three markets:

A day-ahead market for physical delivery of electricity where the Elspot market at Nord Pool is taken as the starting point. This market will in the following text be called the **day-ahead market.**

An intra-day market for handling deviations between production and consumption agreed upon on the day-ahead market and the realized values of production and consumption in the actual operation hour. Regulating power can be traded up to the start of the actual operation hour. Hourly mean-values are used meaning that there is no inter-hour regulation happening in the model. Both flexible producers and flexible consumers offer regulating power on this market, which in the following text is called the **intra-day market.** The demand for regulating power is defined by the forecast errors connected to the wind power production.

A day-ahead market for automatically activated reserve power (frequency activated or load-flow activated). The demand for these ancillary services is determined exogenously to the model. This market will be called the **ancillary services** market.

Several reference years (2000-2002) with historical demand, production, transmission and market data will be used to test and calibrate the model. Scenario calculations for future years where large amounts of wind power have been introduced in the electricity system will be performed.

Furthermore, shorter time periods representing critical combinations of hydrological situations, load situations and wind situations will be simulated to be able to determine the wind power induced reserve power requirements.

At the Wilmar project meetings, the goals for the Planning model have been discussed, which has resulted in the following list of model goals:

Public available data and model: the model (including data) should be public so that the model can be used by other organisations than those included in the project consortium.
Data should be verified and reflect the existing power system.

Electricity Price scenarios: the Planning tool should be able to make well-founded electricity price scenarios.
Market impacts: the model must be able to calculate the impacts of different amounts of wind power in the electricity system on prices found on the day-ahead market and the intra-day market.
Technical impacts: the impact of wind power on the operating patterns of generating plants and storage technologies must be possible to analyse with the model.

With regard to more specific uses of the model, the model should for different configurations of the electricity system (e.g. different amounts of wind power in the system) be able to calculate the marginal values of adding one extra MW capacity of different units such as production units and transmission units. Also, the value of better wind forecasting should be quantified in the model.

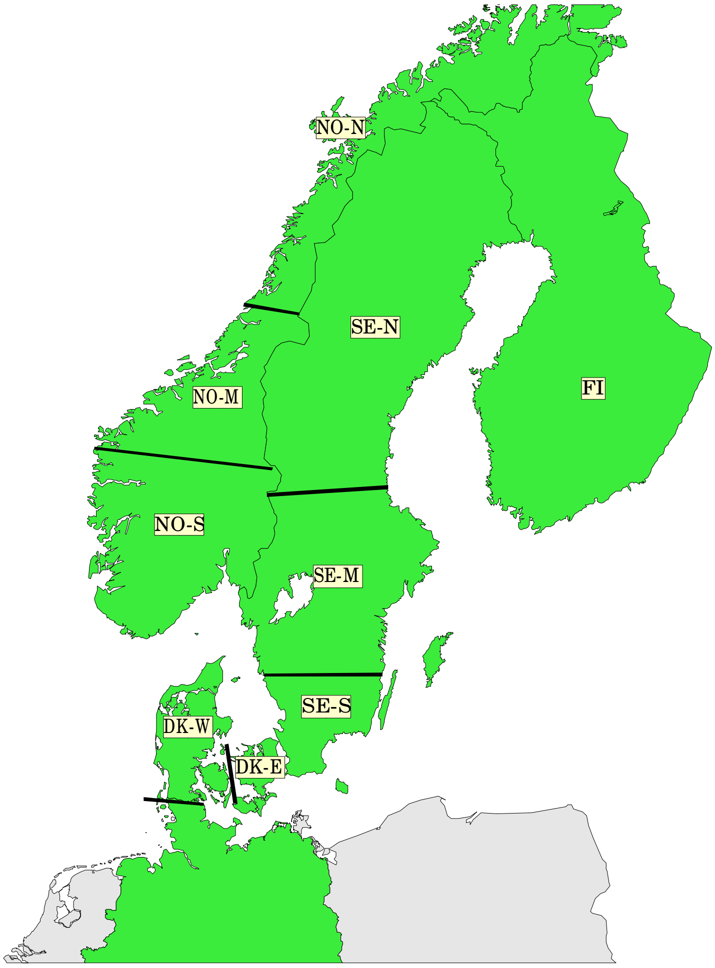

Figure 1: The chosen geographical division of countries into regions in the Planning tool (the division of Germany into regions is not shown in the figure).

Basic Modelling Assumptions

Short Term Marginal Pricing

We assume perfect competition where power suppliers offer electricity to the short-term marginal cost of generation of the power plants. This assumption covers both the day-ahead and the intra-day market. For a given power plant, the short-term marginal cost of generation covers the price of the fuel input and the variable operation and maintenance costs, including start/stop costs.

Number of Markets for Physical Delivery of Electricity

As mentioned in the "Model Goals" section, we suggest to only include three electricity markets in the model, namely the day-ahead market, the intra-day market and the ancillary services market. Over-the-counter/bilateral trading of physical power contracts will not be included in the model, because in a perfect market the power prices of the bilateral contracts will reflect the expected prices on the day-ahead market, and the inclusion of OTC trading will, therefore, have little impact on the model results.

The day-ahead and intra-day markets will cover the whole geographical area, i.e., we assume that the day-ahead markets at Nord Pool and EEX can be analysed as one market[1], and the same goes for the intra-day market.

Other Markets Represented in the Model

Three further markets are taken into account that influence and may interact with the above markets. These are markets for:

District-heating and process heating.

Tradable Green certificates (TGCs).

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[1] Although we assume one market covering the whole geographical area, this does not imply that we will only have one-market price in the whole area. Exchange restrictions between regions will result in different region prices.

CO_2 quotas and Tradable CO_2 Emission Permits (TEPs).

The markets for district heating and process-heating will be represented in the model, because they interact with the electricity markets due to the existence of CHP plants, electrical heat pans and heat pumps.

The TGC market and TEP market influence the functioning of the power system by changing the marginal cost levels for actors bidding at the day-ahead and intra-day markets.

Geography

The countries in the model are subdivided into regions, which again is subdivided into areas. The regions are introduced to handle electricity *transmission* aspects and correspond to bidding areas as seen on the Nord Pool market. Figure 1 shows the regions in the model except the regions in Germany. Germany will be divided into three regions.

Model Overview

Figure 2 shows an overview of the models that either provide input to the planning model or constitute the planning model. The exchange of forecast data and data for the actual operating hour between models is illustrated in the figure. A number of models provide input to the planning model as also seen in the figure. The Planning model consists of two sub models corresponding to optimisation over two different time horizons.

Due to the existence of hydro reservoirs and limitations on the amount of water inflow to the hydropower system the use of hydropower must be optimized over a one-year (or longer) horizon. Furthermore if we assume the existence in the model of a fixed CO_2 quota for the North European electricity system, the CO_2 emissions from the power plants will be subject to a long-term (yearly) restriction.

The long-term model will optimise the use of water inflow and CO_2 quotas over a one-year horizon. The input from the long-term model to the Joint Market model will be one table with the water values (opportunity costs of using stored water) as a function of reservoir filling and time of year, and another table with the CO_2 shadow prices as a function of the fraction of the available CO_2 quota still not used and the time of year.

The Joint Market model will optimise the use of heat and power generating technologies and heat and power storage technologies during a bidding period subject to a flexible demand. More precisely, the model will optimise the sum of consumers' and producers' surplus on both the day-ahead market and the intra-day market (so-called joint optimisation) taking the stochastic nature of the demand for regulating power on the intra-day market into account. This means that for generating technologies with a flexible power output the amount of power offered at the day-ahead market will not always be the maximal power output available, but sometimes they will offer less at the day-ahead market due to an expected revenue from the selling of up-regulation at the intra-day market.

Implementing joint optimisation in the Joint Market model means that the amounts and marginal costs of regulating power available in a future operating hour as a function of the regulation needs in the bidding period will be determined in the Joint Market model.

Furthermore the Joint Market model takes into account that some part of the available production capacity must be reserved for providing automatically activated reserve power. The distribution of the demand for ancillary services on the power plants available for providing these services is done endogenously in the model by including this ancillary services market in the optimisation of consumers and producers surplus.

The Joint Market model will use water values and CO2 shadow prices obtained from the Long Term model and input from other models to determine the short-term marginal costs of different supply technologies.

Combined with the heat and power demand curves obtained from the heat demand and power demand models, and combined with forecasts of the amount of up- or down regulation needed in the actual operating hours, the day-ahead market model for each operating hour in the bidding period determines production, consumption and prices on the day-ahead market. The demand for either up- or down-regulation in each hour in the bidding period is calculated by comparing the forecasted values of wind power production and power demand (and maybe other parameters) with the realised values. Having determined the realised state, the results from the Joint Market model will determine how the units were actually

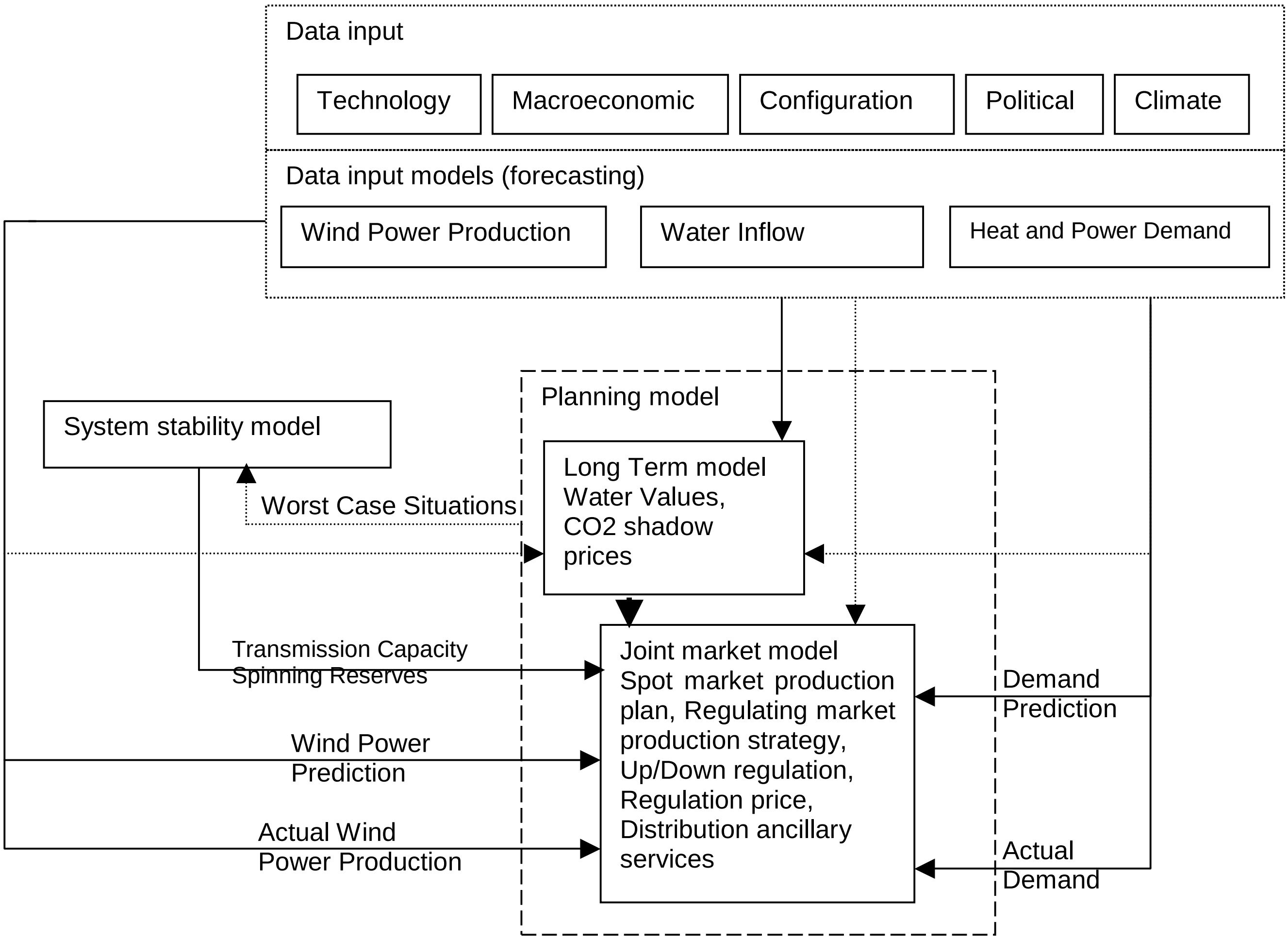

Figure 2: Overview of the data input and models that either provide input to the Planning model or constitute the Planning model. The models shown will exchange data and some of the data flows are illustrated in the figure.

operated during the day-ahead market period and the resulting prices on the intra-day market.

The market crosses at the day-ahead and intra-day markets will determine the dispatch of the generating units and this furthermore determines the power flows in the system (the dispatch being modified in the presence of bottlenecks in the transmission grid). Furthermore the market crosses is based on a marginal cost approach, so the difference between the prices obtained at the day-ahead and intra-day markets and the marginal costs of a given unit will determine the profit of operating the unit in the electricity system.

Status for Planning model development

The first version of the planning model will be tested in the beginning of 2004.

Wilmar Partner Institutions and Contacts

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