German Energy Agency Launches Energy Economy Study for the Integration of Wind-Power Facilities into the Grid

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Abstract— **The focus of the present paper is on approaches to questions and solutions connected with the development of wind power and the integration of wind power into the German electric power-supply system. Fundamental questions are explained and deficits shown. Approaches to solutions are expected from a study being conducted under contract for the German Energy Agency GmbH (dena), which is to be completed in 2004. The stakeholders and goals of the study are presented.**

Index: energy economic study, power station, transmission grid, wind energy

I. Introduction

The electric power supply is an important locational factor for the development of a national economy. Necessary energy-economy and energy-policy decisions of medium and long-term consequence designed to promote a favorable climate for investment for sustainable commercial development in an industrial country like Germany are increasingly being taken in an international context. At present, the basic conditions are undergoing an extraordinary change: In addition to requirements stemming from the liberalization and globalization of the economy, including the energy industry, the international requirements for environmental and climate protection are gaining increasing importance. This growing priority of place will necessarily be transformed into concrete European and national policy decisions.

In order to reduce global environmental problems connected with conventional power generation from gas, coal, oil and nuclear fuel problems such as the greenhouse effect, consumption of finite resources, air pollution and /or the risks of radiation and permanent waste deposits – the electric-power supply system will have to change. This development has already started in Germany and in some other countries.

At present, the energy supply mix for electric power generation in Germany is dominated by nuclear and fossil sources of energy. To date, the share of the renewable energies only amounts to a single-digit percentage figure (see fig. 1). In addition to hydroelectric power, wind power generation has a significant and increasing share.

In Germany, changes and new challenges for the energy supply systems are derived primarily from the goals of the Federal Government to achieve a regenerative sources share of 12.5% of overall power generation by 2010, and of 20% by 2020 [6].

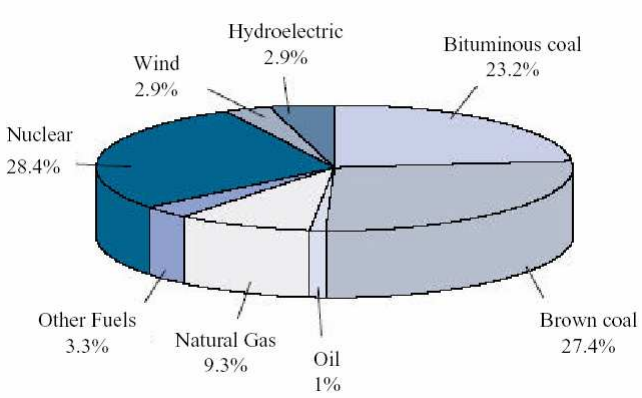

Figure 1: Gross power generation by source of energy in Germany in 2002 [2]

A. The Integrated Power Grid System

It is the task of the integrated transmission system to synchronize the different electric generation and consumption characteristics. Specific demand patterns of single consumers (households/ enterprises) and/ or regions (urban/ rural) must be interconnected with the different power stations, each with its own costs and load characteristics. The integrated generation cooperation system is designed to lower the overall system costs as well as to ensure a high level of supply security and reliability.

The transmission system operators are responsible for the secure and reliable functioning of the integrated system. In Germany, the transmission system (see fig. 2) are owned by four corporations. They compensate for foreseeable and also unexpected load fluctuations, power station failures and bottlenecks in the transmission system of their control zones. They must maintain reserves for system services, in order to be able to offer their customers a high degree of supply quality, particularly with regard to frequency and voltage level. For this purpose, they use primary-control, secondary-control and minute-reserve capacities, and, in particular cases, power stations for hourly-reserve capacities, which can feed power into the grid in case of extended power-station failures or load changes.

To achieve supply security and net stability, the transmission grids have been improved in recent decades,

mainly in accordance with the requirements of fossil-fuel and nuclear-power stations. The ever larger power station blocks and the concomitant requirements on regulation and reserve capacities have very strongly characterized grid expansion in the past.

In recent years, a new aspect has been added: In regions with a high share of wind power in the power supply, such as in the northern German states of Lower Saxony, Schleswig-Holstein, Mecklenburg-Hither Pomerania and Brandenburg, the transmission network operators must not only handle the uncertainties of load forecast, but also the characteristics of wind availability and the resulting fluctuations of the power fed into their grids.

Methods for the forecast of wind output have already been initially developed and tested. Due to the stochastics of wind speed, however, forecast errors cannot be entirely avoided. The transmission network operators can therefore include only a part of the installed wind power capacity in their plans for regulation capacity to cover the load demand, depending on weather conditions.

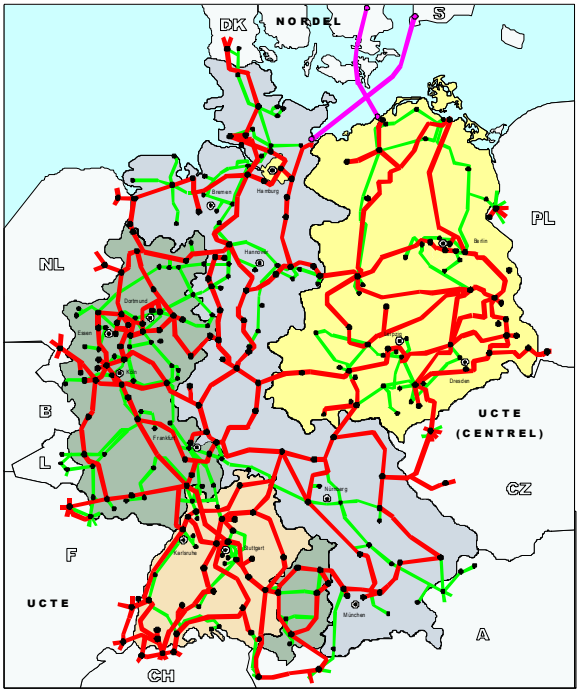

Figure 2: The grids of the four transmission network operators in Germany (simplified representation of the 380 and 220 kV grid) [12]

The forecast error depends largely on the forecast time period. The power station schedules have to date been prepared based on a 24-hour forecast. The forecast error can be reduced by using a four-hour prediction time period instead of a full-day forecast (see curves in fig. 3).

To compensate for the forecast errors, the transmission grid operators buy a “positive” as well as “negative” reserve capacity from the power station operators. “Positive” reserve capacity covers the load at unexpectedly small power generation from wind power facilities. The “negative” power station output is taken by the grid if wind availability is unexpectedly high and the produced wind power must be fed into the transmission grids and paid for as a priority due to the legal requirements under the Renewable Energy Law (EEG).

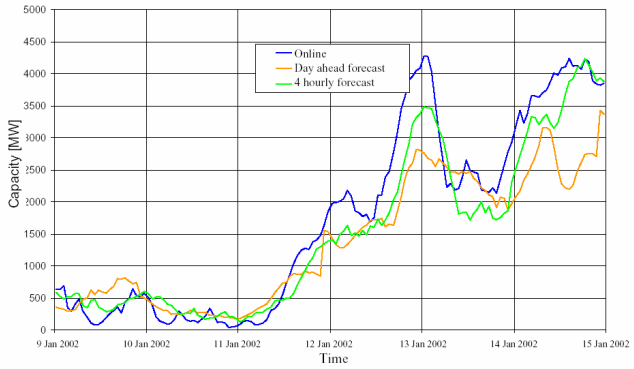

Figure 3: Curve of wind-power feed-in, full-day and short-term forecast (previous-day and four-hourly forecast) [10]

B. Power Station Renewal Cycle

During the next twenty years, a major renewal and restructuring process will take place in the German electric power system (see fig. 4). Statistically speaking, of the gross power generation capacity of some 121,000 MW presently installed in Germany, about 40,000 MW worth of fossil-fuel-powered capacity will go off-line for reasons of age by 2020. In addition, the implementation of the nuclear-power consensus will result in about 18,000 MW of nuclear-power capacity being shut down.

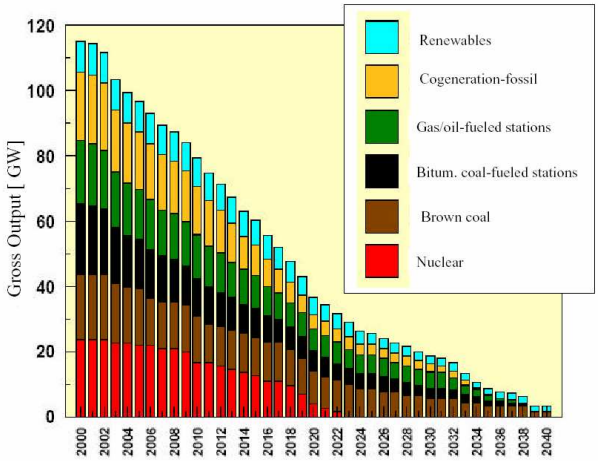

Figure 4: Development over time of the installed power station capacity if there were no substitute or new investments (Public supply, industrial and rail power stations, renewable facilities) [9]

Planning for upcoming replacement investments in the fossil-fueled power station area is also being influenced by the further increase in the share of regenerative sources of energy in the power generation mix, and by the priority rule of the EEG favoring renewables. This will mean that the technical characteristics of power stations will for some time have to be adapted to the fluctuations of wind power,

which will enjoy feed-in priority. Particularly, the gradient of output changes in regular operation, the duration of start-up procedures up to grid synchronization, and the degree of effectiveness in full and partial load operation will have to be optimized for fossil power stations with regard to the integration of wind power into the transmission system.

C. A Look at the Development of Wind Power

Decisive for the success of wind power was the Electric Power Feed-In Law passed in 1991 for renewable energies in Germany, which was replaced by the EEG in 2000. Since then, wind power has been supported together with such other renewable energies as hydroelectric power, solar energy and biomass.

The substantial prerequisites for the success of the wind industry, which has a decade of extremely dynamic growth behind it (see Figure 5), are:

- the compensations fixed legally for the power feed-in from renewable energy sources and
- the priority purchase requirement for the renewable power produced imposed upon transmission system operators.

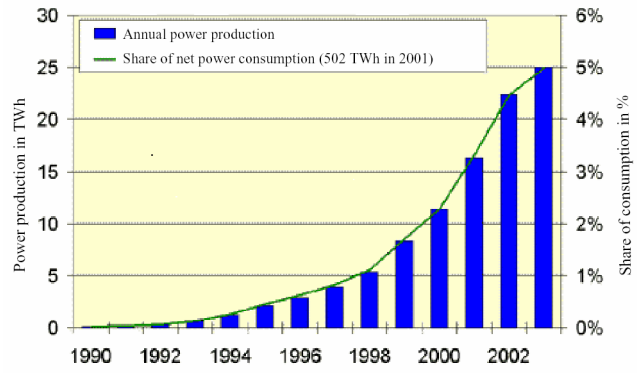

Figure 5: Power production from wind-power facilities [6]

Annual additional construction of wind power facilities in Germany averaged 260 MW during the period from 1990 to 1997; by 2002, it had increased to a total capacity of 3247 MW. For comparison purposes: The wind power capacity newly installed in 2003 in Germany is approximately equal to all the capacity built over the past twenty years in Denmark, the country that pioneered wind power. Altogether, over 14,600 wind power facilities were in operation in Germany in September 2003, with an output totaling some 13,400 MW. This corresponds to $^1/_3$ of the wind power capacity installed worldwide (see fig. 6).

The technical development has led to larger and more efficient facilities. The mean capacity per facility has increased ten-fold, from 0.16 to 1.55 MW, during the period between 1990 and 2003. The first 4.5 MW plants are now in operation in Germany – in Magdeburg and in Emden – with rotor diameters of over 100 m.

According to the Federal Association for Wind Power, over 45,000 people were employed in the wind industry in 2003 [3].

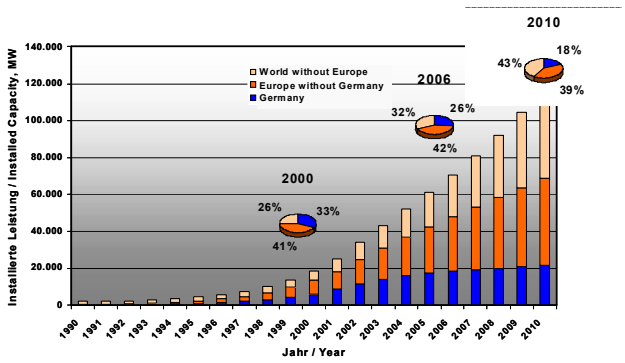

Figure 6: The past and the future: Installed wind power capacity in Germany, Europe and the world [7]

D. New Markets for Wind Power

During the coming years, the development of the wind power will slow down in Germany. According to a market forecast by the German Wind Power Institute (see fig. 7), annual new installation of wind power capacity in Germany will drop considerably. Onshore new construction will come to a complete standstill around the year 2012, according to the forecast. Even today, suitable locations in the North and Baltic Seas are being explored for offshore wind power, and repowering – the replacement of old, smaller plants by more modern, more efficient ones – is being prepared. Moreover, the export of wind-power facilities, which dena is supporting with its Renewable Energies Export Initiative, will increase in importance.

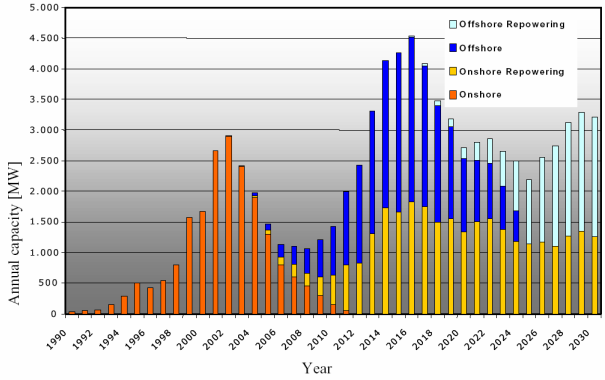

Figure 7: Development of wind power in Germany by 2030 – annual newly installed capacity and repowering, onshore and offshore [7]

In Germany, the construction of offshore wind power stations is seen as a promising approach for the sustainable use of wind power: The "Strategy ot the German Government on the Use of off-shore Wind Energy" adopted by the German Federal Government in 2002 [1], became part of the national sustainability strategy. The goals for offshore wind power in Germany include the offshore installation of:

- at least 500 MW of wind-power capacity by 2006; and
- about 3,000 MW of wind-power capacity by 2010.

In the long term, i.e. up to 2030, it is considered possible to develop locations in Germany's Exclusive Economic Zone (EEZ) in the North and Baltic Seas with a potential for wind power capacity totaling up to 25,000 MW, or power production of 70-85 TWh. Various research projects have been initiated for the gradual, environmentally and conservationally compatible development of offshore capacity in order to solve possible technical, ecological and economic issues [11].

For the further development of wind power, the integration of on and offshore wind power capacities into the integrated power system is now on the agenda. Concepts for the incorporation of efficient wind-power stations are seen as technically practicable. As a prerequisite for an efficient integration of more wind-power stations into the integrated system, the following requirements are being discussed:

- improved grid compatibility of wind power stations; provision of system services (real and reactive power, short circuit behavior, start-up and shut-off procedures);
- improved usage and adaptation or reinforcement of available grids, as well as the construction of new power-line routes on and offshore; and
- Optimization of the conventional power station park for the provision of regulation and reserve capacity.

Due to the renewal and restructuring processes in the German electric power system which will have to be carried out in any case, and due also to the established environmental and energy-policy objectives for the promotion of renewable energies, fundamentally favorable conditions exist for the solution of these complex issues. However, there is to date no overall concept for the energy economy which might address these issues in their overall context.

II. Framework of the Energy Economy Study for the Integration of Wind-Power Facilities into the Grid

A. *Stakeholders*

In September 2003, the German Energy Agency contracted a study for the development of an overall concept for the further development of wind power utilization in Germany, titled *Energy-Economy Plan for the Grid Integration of Wind Power in Germany, Onshore and Offshore, through 2020*. The investigations are to be carried out by a consortium (German Wind Energy Institute GmbH (DEWI), E.ON Net GmbH, Energy-Economy Institute at the University of Cologne (EWI), RWE Net AG, Vattenfall Europe Transmission) under direction of the EWI (Prof. Dr. W. Schulz).

Intermediate and final results are to be checked by external experts (Prof. Dr. J. Schmidt, of the Institute for Solar Energy Supply Technology, Kassel, and Dr. M. Schmieg of DIgSILENT GmbH, Gomaringen).

The study is proportionately financed by associations and companies in the wind-power, grid-operation, facilities manufacturing and conventional power-plant industries, as well as the Federal Ministry of Economics and Labor.

The following stakeholders are involved in the study: Federal Wind Energy Assoc., Enova Energiesysteme GmbH & Co KG, E.ON Netz GmbH, EWE AG, Offshore-Bürger-Windpark Butendiek GmbH & Co. KG, Offshore Forum Windenergie, Plambeck Neue Energien AG, Projekt GmbH, RWE Net AG, Vattenfall Europe Transmission GmbH, VDMA Fachverband Power Systems e.V., Energy Industry Assoc., Grid Operators' Assoc., VGB PowerTech e.V., WINKRA-ENERGIE GmbH, Wind Power Industry Assoc., Central Assoc. for the Electrical and Electronics Industry, Federal Ministry of Environment, Conservation and Nuclear Safety, and the Federal Ministry for Economics and Labor. They are directly involved in the drafting of the study through a project control group and an experts' advisory board. The German Energy Agency has initiated and prepared the overall study project. It directs the Project Control Group and Experts' Advisory Board committees, and is responsible for project management.

B. Goals

The general goals of the dena-study are:

- To ascertain the concrete effects of an amplified development of wind energy in Germany on the German electric-power system;
- To estimate the costs connected with wind power development for the German power supply system and for the conventional power-station park;
- To develop the most cost-effective concept for a gradual expansion of the power supply system in Germany, offshore and on land, for the connection and integration of wind power plants into the electric-power infrastructure through 2020;
- To draft optimization strategies for the power station park, and to ascertain the most cost-effective systemic solutions for the further development of wind power generation on and offshore.

While the study is oriented toward the electric power supply of Germany, Germany's power interchange with its neighboring countries is included in the examination (simplified model see fig 8).

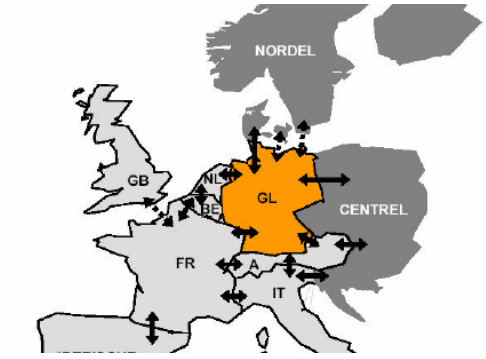

Figure 8: Regional model structure for electric power

exchange [4] (simplified),

Scenarios:

First, the dena-study develops scenarios for amplified use of regenerative sources of energy for 2007, 2010 and 2020. The goal is a spatially highly differentiated image of wind power expansion on and offshore, so that the regional wind power expansion can be assigned to particular grid nodes.

Effects of Wind Power on the Transmission Grids:

Based on the scenarios for wind-power expansion, the effects of wind power on the transmission grids is to be examined. The goals of this "Grids" section of the study are:

- To adapt the transmission grids to the future development of wind power onshore, i.e. to ascertain expansion and reinforcement measures in the German integrated grid system;
- To draft an overall concept for the system design of the submarine cable transmission of offshore wind-park power to connection points on the North and Baltic Seas;
- To determine the investment and operating costs for wind-power-related grid expansion on land, and for the transfer to land of the offshore power;
- To ascertain cost-effective system solutions for power transmission to consumers; and
- To avoid losses in supply reliability for the entire system.

Effects of Wind Power on the Rest of the Power Station Park:

The effects of wind power feed-in on the rest of the power-pant park and the demands on the provision of regulation and reserve capacities are the object of the "Power stations" section of the study. The goals of this section are

- To optimize the power-station renewal cycle, with consideration for the future development of wind power;
- To ascertain the requirements upon power stations, which must provide additional regulation and reserve capacity (in terms of both quantity and technical flexibility) in order to maintain supply security;
- To ascertain overall fuel consumption;
- To make an accounting of CO_2 emissions; and
- To determine the total costs of power generation, including provision of regulation and reserve capacity.

C. Perspective

As has been explained in the above chapters, the electric power supply in Germany is facing change. Agreement among the stakeholders involved is one of the prerequisites for the best possible solutions. This will be particularly necessary if capital-intensive decisions and investments are imminent, the effects of which are to extend over several decades and presuppose a reliable energy-economy planning basis. The study contracted by the German Energy Agency is designed to enable this basic long-term energy-economy planning process, which should be carried out by as many stakeholders as possible.

The results of the dena-study will constitute a basis for policy decisions for the integration of more wind power into the power supply system in Germany. This is to constitute an additional component toward achieving the goal of a sustainable development of the electric power supply. The extent to which the results will affect other countries with high and/or increasing wind-power shares in their electric power supply systems could be an issue in the discussion of these results.

The results of the dena-study are to be completed in 2004 and to be made accessible to a broad audience at an international conference.

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