# Wind Report 2004

Netz

Contents

# Wind Year 2003 – an overview

In 2003, Germany again led the world in wind energy use thanks to the Renewable Energy Act (EEG). At the end of 2003, wind power plants with a total installed capacity of around 14,350 Megawatts (MW) fed German electricity grids. Of this, the greatest proportion at around 6,250 MW was connected in the E.ON control area.

For technical reasons, the intensive use of wind power in Germany is associated with significant operational challenges:

- Only limited wind power is available. In order to cover electricity demands, traditional power station capacities must be maintained as so-called "shadow power stations" at a total level of more than 80 % of the installed wind energy capacity, so that the electricity consumption is also covered during economically difficult periods.
- Only limited forecasting is possible for wind power infeed. If the wind power forecast differs from the actual infeed, the transmission system operator must cover the difference by utilising reserve capacity. This requires reserve capacities amounting to 50 – 60 % of the installed wind power capacity.
- Wind power requires a corresponding grid infrastructure. The windy coastal regions of Schleswig-Holstein and Lower Saxony are precisely the places where the grids have now reached their capacity limits through wind power. At present, just under 300 km of new high-voltage and extra-high voltage lines are being planned there in order to create the transmission capacities required for transporting the wind power.

**Wind power 2003 – statistics**

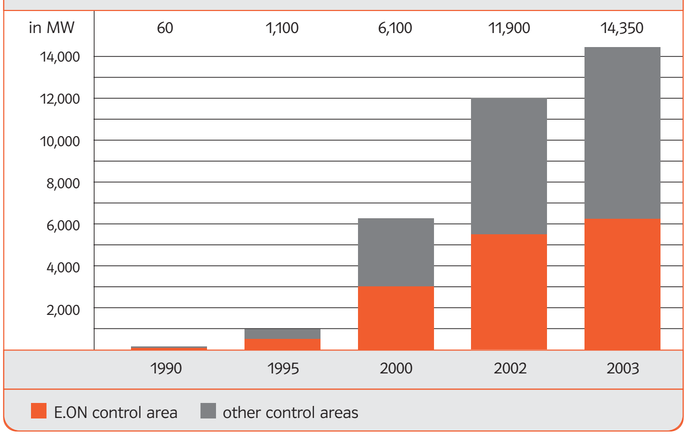
| | |
|---|---|
| Installed wind power capacity in Germany on 31.12.2003 [1] | 14,345 MW |
| – of which in the E.ON control area | 6,250 MW |
| Average fed-in wind power capacity in the E.ON control area | 969 MW |
| Wind power production in Germany [1] | 18.6 TWh |
| – of which in the E.ON control area | 8.5 TWh |
| EEG infeed remuneration for wind power (Germany) [2] | approx. 1,700 million € |
| – of which to be met by customers in the E.ON control area | approx. 510 million € |

[1] Source: Institut für Solare Energieversorgungstechnik (ISET), [2] Source: Verband der Netzbetreiber (VDN)

# Support allows a boom in new wind power construction – E.ON grid territory characterised by new construction

1. Wind power boom in Germany

Total wind power capacity installed in Germany (Sources: ISET, ENE)




## Germany

At the end of 2003, wind power plants with an installed capacity totalling some 14,350 MW were on line in Germany[3].
This was over 2,450 MW or just under 21 % more than in 2002. This means that since 2000, installed wind power capacity in Germany has increased by 137 %. FIGURE 1 shows the installed wind power capacity in Germany.

This means that Germany has become the world's Number One wind power country: In 2003, Germany accounted for approximately one third of the world's and half of Europe's installed wind power capacities. In Germany in 2003, some 18.6 Terawatt hours (TWh) of wind energy were fed in. This meant that arithmetically, it was able to cover just under 4% of Germany's demand for electricity. For this wind power, grid operators paid out 1.7 billion € in supply payments in accordance with the regulations of the Renewable Energy Act. This corresponds to an average payment of just over 9 € ct / kWh.

In Germany, wind power utilisation differs very much on a regional basis. In 2003 also, Lower Saxony and Schleswig-Holstein and therefore the E.ON control area accounted for most of Germany's wind power production.

## E.ON Netz

In 2003, some 8.5 TWh or 46 % of the wind energy produced in Germany were fed in for E.ON Netz (ENE). Approximately 770 million € in infeed payments were paid out for this, with 510 million € of this figure being met by customers in the E.ON control area.

At the end of 2003, a total of 6,250 MW was on line in the E.ON control area – just under 44 % of Germany's entire wind power capacity. This means that in the E.ON control area alone, significantly more wind power generation capacity was installed than on the entire American continent.

For this reason, E.ON Netz GmbH is particularly affected by the technical and operational challenges that massive expansion of wind power brings with it.

[3] Source: Institut für Solare Energieversorgungstechnik (ISET)

# Electricity generation from wind fluctuates greatly

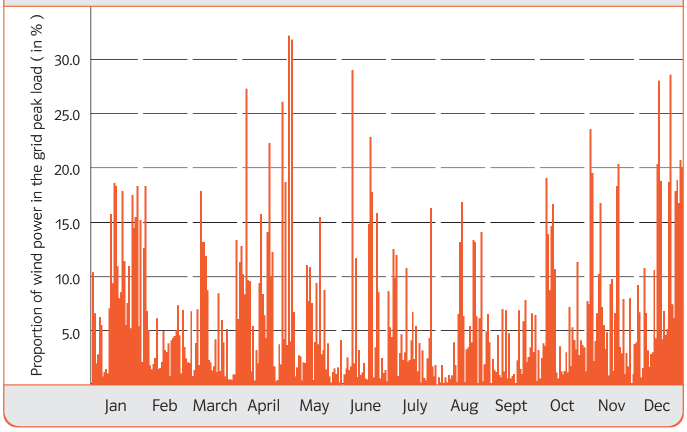
The level of wind power infeed fluctuates greatly depending on the prevailing wind strength. Due to these significant fluctuations, in 2003 the contribution made by wind power production to cover the respective peak load in the E.ON territory varied between zero in real terms and just under one third of the grid load (FIGURE 2).

Looked at over the course of the year, as the annual wind infeed curve shows (FIGURE 3), the availability of the installed wind power plants was relatively low:

- Simultaneous wind power infeed was maximum 4,980 MW, equivalent to just under 80 % of the installed capacity.
- The average fed-in capacity was less than one sixth of the wind power capacity installed in the yearly average.
- Over half the year, the wind power fed-in was less than 11% of the wind power capacity installed in the yearly average.

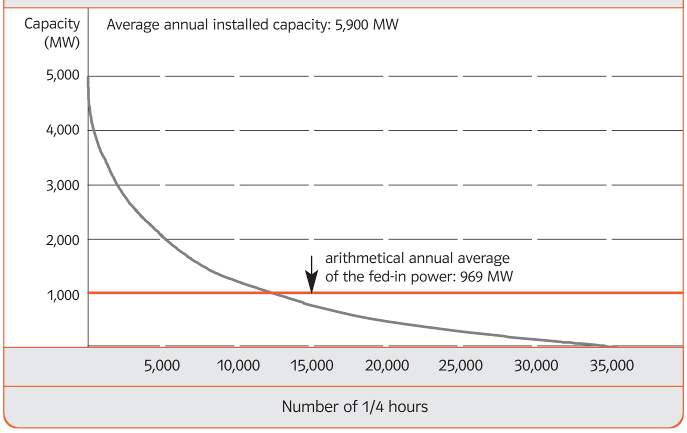
**2. The contribution of wind power**

to covering the daily grid peak load: 2003 between 0.1 and 32 %




**3. Annual curve**

Wind power infeed 2003 in the E.ON control area




**Annual curve**

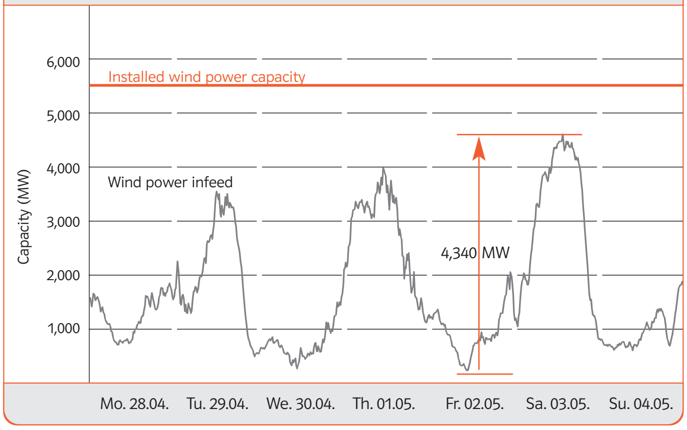
To depict the annual curve, the respective wind power is determined for each quarter-hour of a year and is then shown from left to right in a diagram – in descending order based on the wind power level. If we observe a point on the curve, the associated quarter-hour value (horizontal axis) states how many quarter-hours in the year the wind power plants fed in at least the power that can be read off on the vertical axis. For the remainder of the year, generation was below this power value.

## The weather determines the wind level

Both cold wintry periods and periods of summer heat are attributable to stable high-pressure weather systems. Low wind levels are meteorologically symptomatic of such high-pressure weather systems. This means that in these periods, the contribution made by wind energy plants to covering electricity consumption is correspondingly low.

**4. Strong fluctuations**

in the wind power infeed (E.ON control area: 28.04. to 04.05.2003)




**5. Brief decrease**

possible in the wind power infeed (E.ON control area: 17.11. to 23.11.03)

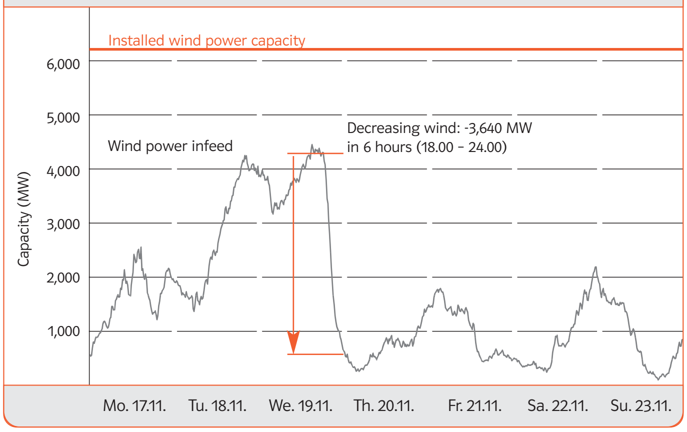


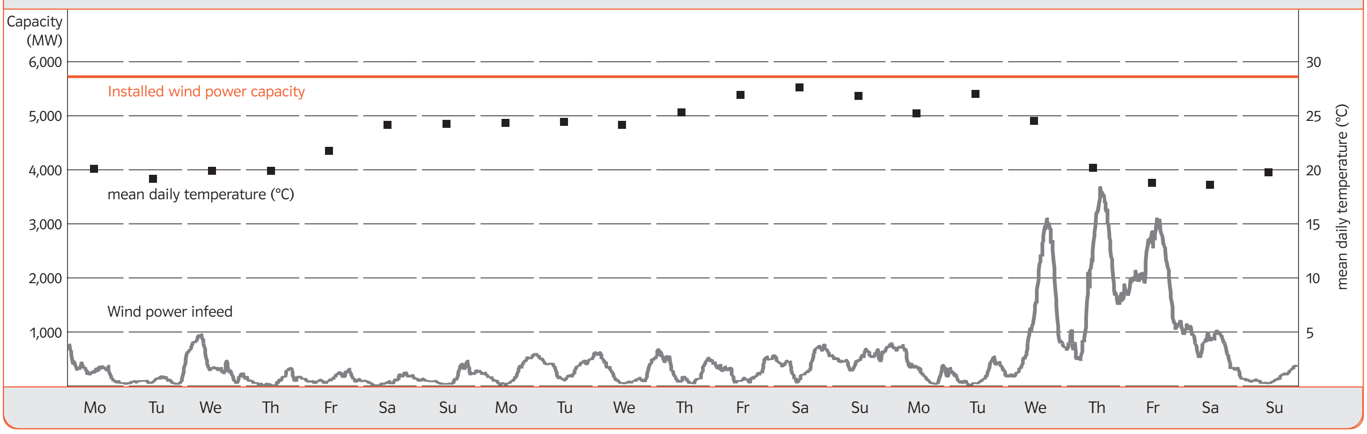

FIGURE 4 shows an example of the wind power infeed pattern in the E.ON territory during a week with strong winds. The difference between minimum and maximum infeed in this example was over 4,300 MW – equivalent to the capacity of six to eight large coal-fired power station blocks.

The wind power infeed changes can occur in a relatively short time. This can be seen in FIGURE 5, which shows the wind power infeed pattern in the E.ON control area in the week of 17th to 23rd November 2003. It is clear that on 19th November, the wind power infeed dropped very sharply – by 3,640 MW within six hours, with an average value of 10 MW per minute.

The experience of the past year has shown that whenever electricity consumption was comparatively high because of the weather, namely during cold wintry or hot summer periods, wind power plants could make only a minor contribution towards covering consumption.

**6. Minor contribution of wind power during the 2003 heatwave**

E.ON control area: 28.07. to 17.08.2003



## Midweek peak load

The midweek peak load is calculated on the basis of uniform international criteria. This day's load curve is used in energy management to characterise the electricity consumption of a grid territory, country etc.

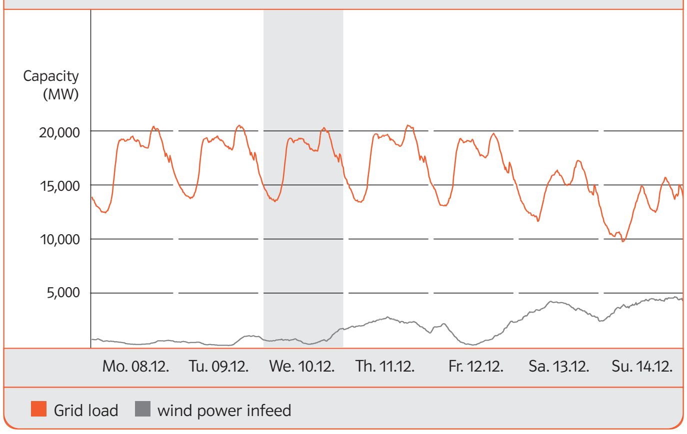
This relationship was again confirmed in Germany during the heatwave of July / August 2003 (FIGURE 6). The summer electricity consumption was at that time at an above-average high level due to the temperature. At the same time, traditional power stations had to partly reduce their capacity so as not to impermissibly heat up the rivers that serve as sources of cooling water. During this phase, wind power production was also very low due to the lack of wind and was not able to contribute towards relieving the strained supply situation.

FIGURE 7 shows that in the winter of 2003 also, the contribution of wind power towards covering load was low precisely in phases of particularly high electricity demand. The wind power infeed curve during the week of so-called "midweek peak load" in the E.ON grid in 2003 is shown.

In order to also guarantee reliable electricity supplies when wind power plants produce little or no electricity – for example during periods of calm or storm-related shutdowns – traditional power station capacities must be available as a reserve. The characteristics of wind make it necessary for these "shadow power stations" to be available to an extent sufficient to cover over 80% of the installed wind energy capacity. This means that due to their limited availability, wind power plants cannot replace the usual power station capacities to a significant degree, but can basically only save on fuel.

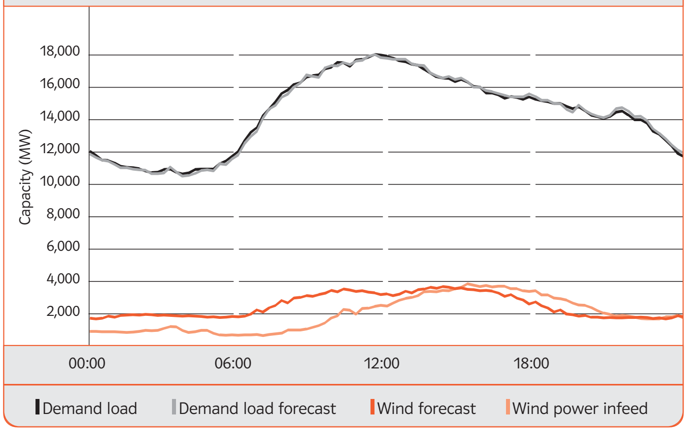
**7. The minor contribution of wind power**

during midweek peak load (E.ON control area: 08.12. to 14.12.03)



# Only limited forecasting possible for wind power infeed – demand for wind-based reserve capacity increases with new wind power construction

8. Precise consumption forecast – wind difficult to forecast (E.ON control area, 14.08.2003)




**Power-frequency control**

The purpose of power-frequency control is to create an equilibrium between generation and consumption in a defined grid territory (control area) at a stable grid frequency of 50 Hz. This is achieved by briefly activating additional generating capacity or by deactivating surplus generating capacity for seconds and minutes.

Large quantities of electrical energy cannot be directly stored. This means that every second, exactly the amount of energy must be fed into the grid that is taken out at the same time. If the amount fed in differs from the amount tapped, this can cause faults or even failure of the supply – as confirmed in 2003 by the wide-scale power failures in the USA, Italy, Sweden and Denmark.

The transmission system operators must therefore at all times ensure a balance in their control areas between generation and tapping (power-frequency control).

Generation in traditional power stations can be easily controlled in line with demand. As a result, in the past it was mainly only the time pattern of tapping from the grid that was relevant to power-frequency control. Thanks to constant consumption behaviour, this tapping can be forecast with a high degree of accuracy.

However, the increased use of wind power in Germany has resulted in uncontrollable fluctuations now also occurring on the generation side due to the stochastic character of wind power infeed, thereby increasing the demands placed on control and bringing about rising grid costs (FIGURE 8).

So that stable grid operation is possible despite the high volatility of wind power infeed, transmission system operators depend on the most accurate possible forecasts of the expected wind power infeed.

To forecast wind power, E.ON Netz uses a complex forecasting system developed by ISET and based on the forecasting data of the German Meteorological Service.

The quality of wind power forecasting is to a great extent limited by the quality of the wind forecasting. Like all weather forecasting, this is only partly reliable.

In 2003, the average negative forecasting error for the E.ON control area was -370 MW, and the average positive forecasting error was 477 MW.

However, during individual hours the deviations reached much higher levels of up to +/-2,900 MW. This was equivalent to just under half the installed wind power capacity. FIGURE 9 shows the frequency distribution of the forecast error.

The transmission system operator must balance out differences between the wind power forecast and the wind power actually fed in by using the controlling power range and reserve capacity.

Of crucial importance to the wind-related demand for reserve capacity is the expected maximum forecast deviation and not, for example, the mean forecast error. This is because even if the actual infeed deviates from the forecast level only on a few days in the year, the transmission system operator must also be prepared for this eventuality and have sufficient capacity available so that a reliable supply is still guaranteed. FIGURES 10 and 11 show examples of the deviation between the actual wind power infeed and the forecast.

The massive increase in the construction of new wind power plants in recent years has greatly increased the need for wind-related reserve capacity in Germany. In 2003, costs amounting to around 100 million € for this were incurred in the case of E.ON Netz alone.

Operational experience over the past few years has shown that reserve capacities in the order of magnitude of up to 60 % of the installed wind power capacity must be kept for wind balancing in years when wind levels are normal. The need for reserve capacity and the resulting costs will therefore continue to rise in future parallel to the further expansion of wind power.

In 2003, wind levels and therefore also the absolute fluctuation range of the wind power infeed were at above-average high levels. This meant that in retrospect, only reserve capacity amounting to around 50 % of the installed wind power capacity actually had to be used.

### Forecasting error

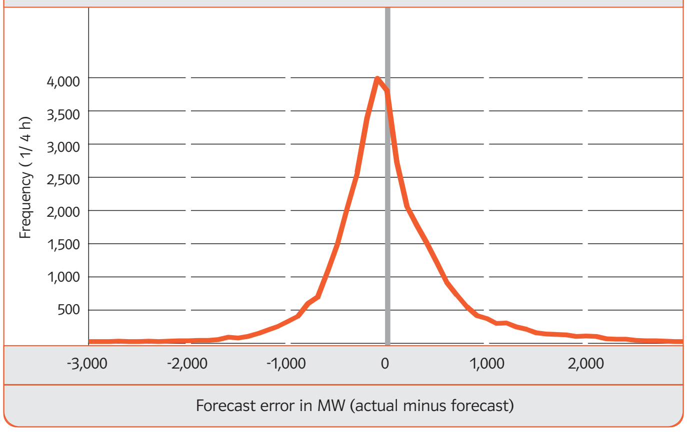
The forecasting error is calculated from the actual wind infeed minus the forecast wind infeed. A forecasting error of –1,000 MW therefore means that the forecast was 1,000 MW too high.

### Wind-related reserve capacity

This means power station capacities that can be brought onto or taken off load at short notice and which are reserved with the power station operators by the transmission system operators for a fee to be used for balancing out deviations between the actual and forecast wind power infeeds.

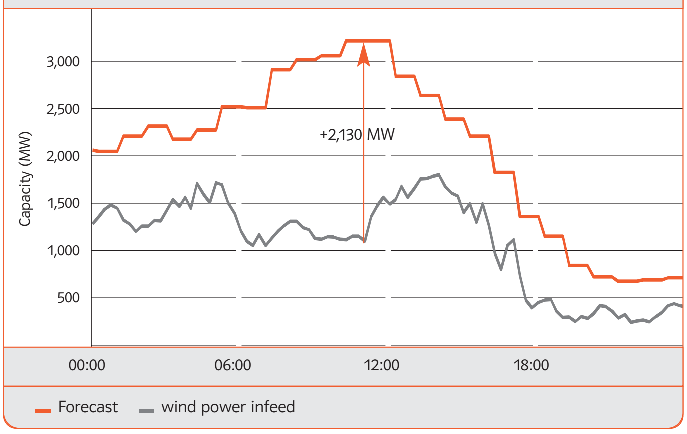
**9. Frequency distribution of the forecast error**

for wind power infeed 2003 in the E.ON control area, 2003



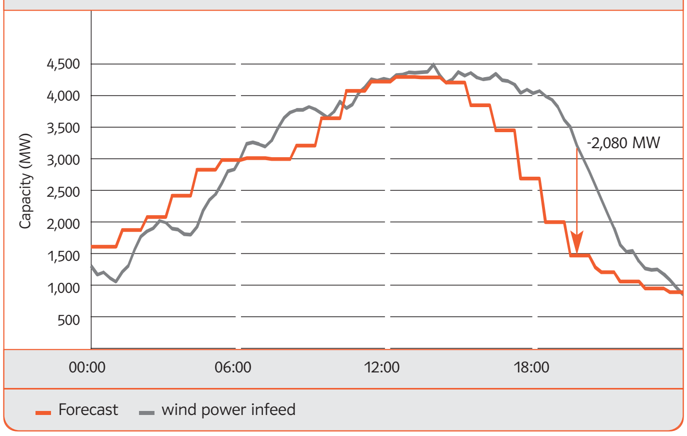

**10. Less wind than forecast**

Positive reserve capacity required (Example: E.ON control area 01.07.03)




**11. Wind blows longer than forecast**

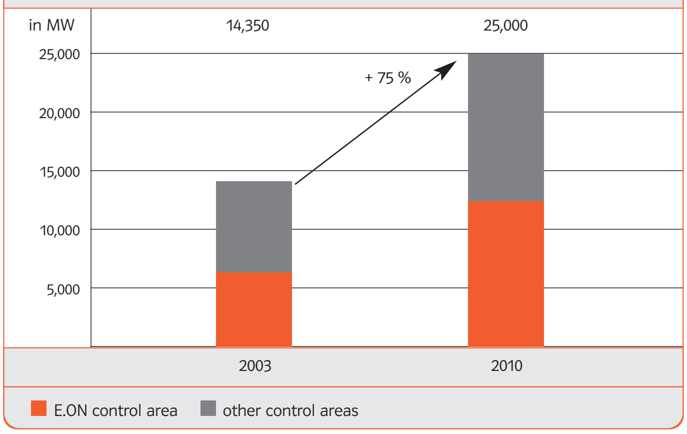
Negative reserve capacity required (Example: E.ON control area 03.05.03)



# Wind energy leads to regional price distortions – even load distribution overdue

12. Wind power boom to continue

Installed wind power capacity 2003 – 2010 (Sources: DENA, ENE)




In 2003, the expense required for balancing out the wind power fluctuations differed greatly in the four German control areas, depending on the wind power capacities installed there. Approximately half the wind balance was done by E.ON Netz GmbH, even though its share of the ultimate consumer sales in Germany was only 30 %. The Renewable Energy Act provides for national distribution of the EEG infeed remuneration and energy quantities (work equalisation). However, so far there is no law covering a national allocation of the costs incurred for balancing out the fluctuating wind power infeed (capacity equalisation). The result of this is a higher grid utilization cost burden in the "windy" control areas.

In the E.ON Netz territory alone, almost 10,000 MW of on-shore wind power capacity and some 2,500 MW of offshore wind power capacity are expected by 2010. In total, according to forecasts of the German Energy Agency (DENA), the wind power capacity installed in Germany should increase by 75 % to 25,000 MW by 2010 (FIGURE 12).

Demand for wind-based reserve capacity will continue to increase accordingly. If the framework conditions were to remain unchanged, this would lead to a further intensification of the existing imbalance between the transmission system operators.

In addition to the already existing allocation mechanisms in the EEG, it is therefore necessary to also establish a simultaneous proportional involvement of all transmission system operators in the wind equalization program. Technical implementation of such a legal ruling is possible within a few months. It would eliminate existing wind-related grid price distortions and also reduce the total wind-related reserve requirement in Germany, because wind patterns are not the same in all regions of Germany and the wind power fluctuations would therefore partly balance each other out.

# Wind power needs a corresponding grid infrastructure – grid expansion necessary

One decisive factor for the further expansion of wind energy use will be the capacities of the electricity grids. Today, the grids in some regions of Germany, for example in Schleswig-Holstein and Lower Saxony, are already approaching their capacity limits. When the wind is strong, they are unable to take any additional wind power.

The reason: Up to now, electricity supplies in Germany have largely been decentralized, with power stations having been built across the country as close to the points of consumption as possible. This has made it possible to avoid transporting electricity across long distances.

The power grids were built to bring the energy from these power stations to the consumers, which has meant that, expressed in simple terms, energy has always flown in one direction and only across relatively short distances. This has changed with the boom in wind energy. An increasing number of wind parks have been and are being built primarily in coastal and relatively sparsely populated areas of low consumption, which in periods of strong wind generate more energy than the area in question consumes at the same time. Consequently, this surplus energy must be transported over long distances. The line grids in the coastal regions can no longer do this in their current state without limits.

The Renewable Energy Act obligates grid operators to remedy wind-related grid congestion at their own expense. As a transmission system operator in the north German coastal states of Schleswig-Holstein and Lower Saxony, E.ON Netz GmbH is particularly affected by this obligation.

To remedy wind-related congestions, E.ON Netz is planning around 110 km of new 110 kV high-voltage lines in Schleswig-Holstein, the cost of which is estimated at 70 million € .

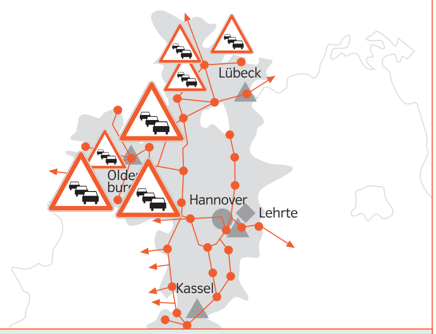
Approximately 180 km of high-voltage and extra-high voltage lines are being planned in Lower Saxony, including for the first time a new wind-related extra-high voltage route in the Oldenburg Münsterland. The estimated cost for the line construction in Lower Saxony is around 120 million € (FIGURE 13).

**13. Wind-related grid congestions**

in the E.ON control area necessitate grid expansion in Schleswig-Holstein and Lower Saxony

**Schleswig-Holstein:**
110 km new high-voltage lines, cost approx. 70 million Euros

**Lower Saxony:**
180 km of new extra-high and high-voltage lines, cost approx. 120 million Euros




In both cases, the plans are based on pure onshore expansion scenarios. If offshore wind parks will also be built on a greater scale in the future, additional grid expansion measures would also be necessary in the extra-high voltage grid.

Wind power does not only cause regional grid congestion in the north German Federal States. In Schleswig-Holstein and Lower Saxony, far more wind power is generated under conditions of high wind and low load than is consumed in these states. Since in the coming years the expansion of wind power is set to progress on the basis of political will, by the end of the decade at the latest, Schleswig-Holstein and Lower Saxony will be wind power export states across long distances. The same will probably also then apply to Mecklenburg-Vorpommern if the current offshore plans become reality. This will drastically change the current principle of decentralized electricity generation close to the point of consumption. Cross-border electricity trading will also be significantly hindered by increased grid congestion. New transport lines will be necessary on a large scale in order to bring wind power generated on the coast and at sea to the consumer centres in the Ruhr or Rhine-Main region. In its expert assessment relating to this, the Institute for Electrical Plant and Energy Management of the RWTH Aachen assumes that by 2016, up to 1,500 km of new high-voltage and extra-high voltage power lines will be required for this in Germany[4].

[4] Energiewirtschaftliche Tagesfragen 9/2003, Page 566

# Grid expansion needs planning and investment security

The grid operators require planning and investment security for expanding the wind power grid. Politicians, wind park planners and grid operators must therefore develop realistic scenarios for the further expansion of wind power – including offshore – that can serve the grid operators as a planning basis for the additional capacity requirement. As part of the so-called DENA study, a national reference scenario is being worked on for the first time by the German Energy Agency in collaboration with plant operators, wind park planners and politicians, with the support of E.ON Netz GmbH.

# Grid expansion and new wind power construction must take place in parallel

Due to the often lengthy approvals procedures that are involved, comparatively long realization times must be expected in Germany for the construction of new high-voltage and extra-high voltage power lines, as is currently becoming clear in the case of the power line construction plans in Schleswig-Holstein.

It is therefore necessary to speed up the approvals procedures for the construction of required new lines for wind power and to in future link the approvals procedures for new wind parks to the approvals procedures for the required grid expansion. There is a risk of bad investments being made if this is not successful: Wind parks without a sufficient grid connection, or lines set up for wind power but for which there is no supply.

# Generation management – grid safety and renewable energy in harmony

In Schleswig-Holstein, due to the many wind power plants installed there, the grid capacities are now exhausted when there is strong wind. Although the approvals procedures for the required grid expansion measures have already been initiated, it can be assumed that it will be several years before the planned power lines are realized. So that additional wind parks can still be brought on line until completion of the grid expansion, in 2003 E.ON Netz GmbH introduced what is referred to as "generation management" in Schleswig-Holstein.

This refers to a temporary reduction in the power fed in by wind energy plants when there is strong wind in order to protect grid infrastructure such as overhead lines or transformers against supply-related overloads and to avoid supply failures.

The aim is to guarantee a reliable electricity supply and still make optimum use of the grids for the receiving electricity generated from wind power.

At present in Schleswig-Holstein, wind power plants with an installed capacity of 600 MW – just under one third of the total wind power capacities in Schleswig-Holstein – are involved in the generation management.

Until the grid expansion is completed, new wind parks in Schleswig-Holstein can be granted only conditional grid connection approval. A condition is agreement to participate in the generation management.

Without generation management, further expansion of wind power in Schleswig-Holstein is for the time being not possible.

In view of the wind power-related grid congestions in Lower Saxony, E.ON Netz is also introducing generation management there.

### How generation management functions in Schleswig-Holstein

Based on grid calculations, the E.ON grid has been divided up into ten regions in Schleswig-Holstein.
Every impermissible load on equipment is automatically forwarded to the grid management centre of E.ON Netz GmbH in Lübeck. Following identification of the affected region, a signal is sent to the wind parks feeding in electricity in this region.
The signal defines the maximum active power at which the region’s wind energy plants can feed electricity into the grid in view of the current grid situation.
The wind park operators are responsible for the demanded reduction in the infeed power. They therefore make an essential contribution towards maintaining a safe supply. Direct power control of the plants by E.ON Netz is not possible for technical reasons.
When sufficient grid capacities are available again, the power restrictions are immediately lifted again – also via a signal sent to the respective wind park management system.

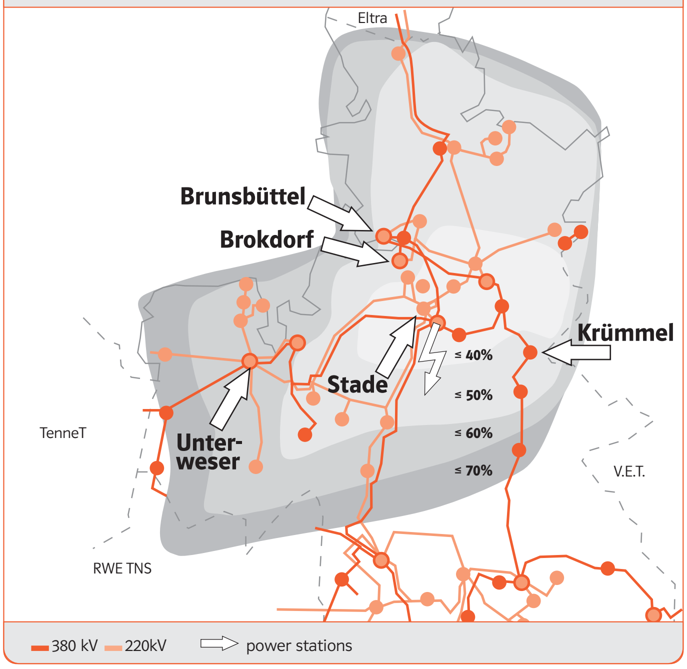
# Wind energy plants must in future also contribute towards stable grid operation

The foreseeable further expansion of wind energy in Germany and Europe means that in future, it will be necessary to pay more attention than before to supply reliability when designing new wind energy plants.

The operational behaviour of wind power plants has so far differed greatly from that of traditional large power stations. Due to the massive and ongoing new expansion of wind power, it has therefore become increasingly difficult to guarantee the stability of the electricity supply – particularly in the event of a power failure.

**14. Potential gradient area**

Voltage dip in the case of a fictitious three-phase fault




## Potential gradient area

As an example, FIGURE 14 shows the voltage dip as a percentage of the grid nominal voltage in the case of a fictitious three-phase fault close to the Dollern substation.

In this case, the grid voltage would briefly fall to below 80 % everywhere. This would result in the sudden failure of almost the entire wind power supply in this area.

This means that wind power plants do not contribute to the same extent towards stabilising the grid frequency and to voltage stabilising as is the case with traditional power stations, which are actively involved in grid control.

But even more serious is the fact that wind power plants of the usual type have so far disconnected themselves from the grid even in the event of minor, brief voltage dips, whereas large thermal power stations are disconnected only following serious grid failures.

Faults in the extra-high voltage grid can therefore result in all wind power plants in the affected region failing suddenly. This means that within a very short time, the wind power supply of up to 3,000 MW can fail, thereby putting the grid stability at risk.

## New grid connection regulations for wind power plants

Even today, the failure of wind power generation in the event of grid problems is barely possible to master via system technology. With regard to the further expansion of wind power, E.ON Netz therefore published new grid connection regulations in August 2003[5]. The minimum technical requirements for wind power plants defined therein are essential in the interests of grid stability and supply reliability.

In future, wind power plants may no longer be disconnected from the grid following a grid failure. They must operate without reaction and must be able to act so as to provide voltage back-up on the grid when there is an operational fault. Like conventional power stations, wind power plants must in future also feed active power into the transmission system to support the grid frequency immediately after the grid failure has been remedied.

[5] Download the grid connection regulations under www.eon-netz.com

## A profile of E.ON Netz GmbH

E.ON Netz GmbH is responsible for the electricity transport grid of the E.ON Group. With over 32,500 kilometres of high-voltage and extra-high voltage lines from Flensburg to Garmisch-Partenkirchen, the company is one of the main electricity grid operators in Europe. The control area of E.ON Netz GmbH covers one third of Germany. More than 20 million people profit from a reliable system operation. With a total of over 6,000 MW of installed wind power capacity in its control area, E.ON Netz makes a leading contribution on both a national and a European scale towards integrating wind energy into the electricity grid.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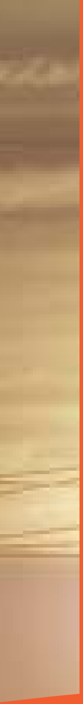

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