Wind Report 2005

E.ON Netz

Contents

Summary

In 2004, Germany was once again the global world leader in the production of wind power. At the end of 2004, wind energy plants with an installed capacity of 16,400MW supplied the German electricity grids. The greatest proportion of this capacity, 7,050MW, was connected in the E.ON control area. E.ON Netz, the transmission system operator of the E.ON Group, consequently makes a key contribution towards the technically and commercial optimum integration of wind power into the electricity supply systems.

However, the intensive use of wind energy in Germany is associated with three key operational challenges.

- **Wind energy is only able to replace traditional power stations to a limited extent.**
  Their dependence on the prevailing wind conditions means that wind power has a limited load factor even when technically available. It is not possible to guarantee its use for the continual cover of electricity consumption. Consequently, traditional power stations with capacities equal to 90% of the installed wind power capacity must be permanently online in order to guarantee power supply at all times.
- **Wind power feed-in can only be forecast to a limited degree.**
  The transmission system operator must balance out variations between the forecast wind power and the actual feed-in using the short-term use of reserve capacity. In order to keep the reserve capacity requirement as low as possible, E.ON Netz uses a forecasting system jointly developed with the Institut für Solare Energieversorgungstechnik (ISET), which is continuously being developed.
- **Wind power needs a grid infrastructure.**
  The windy coastal regions are precisely the places where the grids have now reached their capacity limits through wind power. High voltage (HV) grids are increasingly reaching their capacity limit and they can take no further electricity from wind farms. As a result, E.ON Netz is currently planning just under 300km of new high and extra-HV overhead lines in Schleswig-Holstein and Lower Saxony. E.ON Netz is doing everything it can to implement these grid expansion measures as quickly as possible. In order to avoid stopping the connection of new wind farms despite grid congestion, E.ON Netz introduced generation management as a transitional solution. This procedure even became part of the Renewable Energy Act (EEG) in 2004.

Outlook: Threefold increase in wind power in Germany by 2020

According to grid studies by the Deutsche Energie-Agentur (dena), wind power capacity in Germany is expected to increase to 48,000MW by 2020, around a threefold increase since 2004. The possibility of integrating this generation capacity into the supply system remains to be seen. There is a need for considerable changes to the extra-HV grid alone, of around 2,700km. These measures will affect the whole of Germany, not only coastal areas.

Wind power 2004 – statistics

Installed wind power capacity in Germany on 31.12.2004 [1]	16,394MW
– of which in the E.ON control area on 31.12.2004	7,050MW
Average fed-in wind power capacity in the E.ON control area	1,295MW
Wind power production in Germany [1]	26 billion kWh
– of which in the E.ON control area	11.3 billion kWh
EEG feed-in remuneration for wind power (Germany) [2]	approx. € 2.35 billion

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

Wind power boom continues – E.ON Netz leads the way in supply system integration

Germany

At the end of 2004, operational wind farms in Germany had an installed capacity of 16,394MW (Source: ISET). This was around 2,050MW, or 14%, more than in 2003.

This means that Germany remains the world's undisputed number one generator of wind energy. In 2004, Germany accounted for approximately one third of the world's and half of Europe's installed wind power capacities.

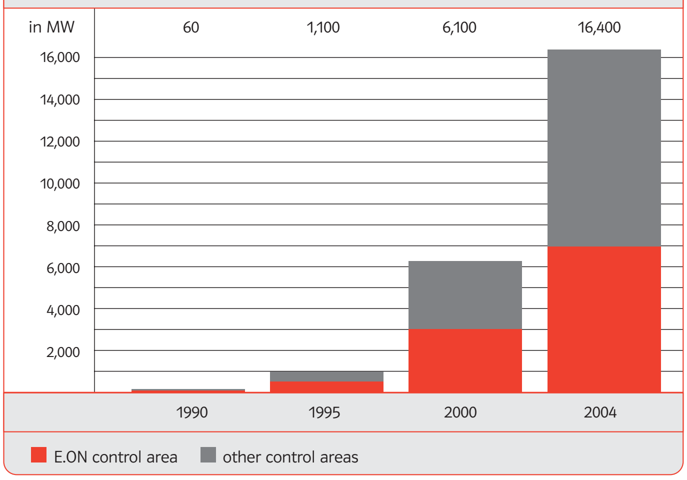
In 2004, there was slightly less wind available than in an average year. In total, German wind farms generated 26 billion kWh of electricity, which is around 4.7% of Germany's gross demand. Wind farm operators were paid a total of €2.35 billion, at an average of €ct 9/kWh. Wind power accounted for approximately two thirds of the total 39 billion kWh of renewable power generated by the EEG. It received a total of €3.6 billion payments through EEG remunerations (Source: VDN).

The pace of new onshore wind farms construction fell in 2004 due to the restricted availability of suitable locations near the coast.

FIGURE 1 shows the evolution of installed wind power capacity in Germany since 1990. The increase in capacity in 2004 was due to new onshore wind farms and the repowering of exisiting wind farms, where turbines were replaced with new, modern and more efficient models.

1. Wind power boom in Germany

Total wind power capacity installed (Sources: ISET, E.ON Netz)



The installed capacity of the wind farms is expected to increase almost threefold by 2020 (FIGURE 2). A large proportion of this forecast increase will come from offshore wind farms, as a large number of these are being planned off the German coast in the North Sea and the Baltic Sea.

E.ON Netz

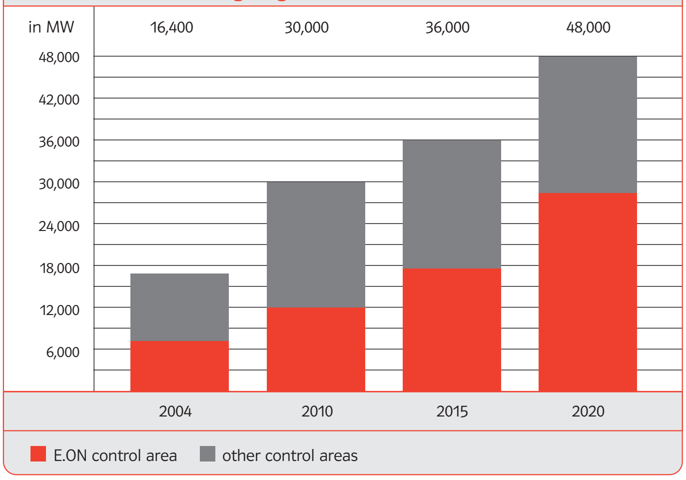
At the end of 2004, wind farms with a total installed capacity of around 7,050MW were connected in the E.ON Netz control area, accounting for 43% of total installed wind power capacity in Germany. As a comparison, the grid load, ie the power coming out of the E.ON transmission grid, was between just under 7,800MW and 21,200MW in 2004.

It is already clear that the greater proportion of the offshore wind farms scheduled to be built off the coast of Germany will feed their power into the E.ON grid. For this reason, E.ON Netz GmbH is, and will remain in future, particularly affected by the technical and operational challenges that this massive expansion of wind power brings with it.

In total, the wind farms in the E.ON control area fed around 11.3 billion kWh into the grid. The wind farm operators in the E.ON control area received feed-in remunerations totalling around € 1 billion.

2. Wind power boom to continue

Forecast new wind power construction in Germany up to 2020 (Source: Deutsche Energie-Agentur dena)



Wind power generation – weather restricts availability

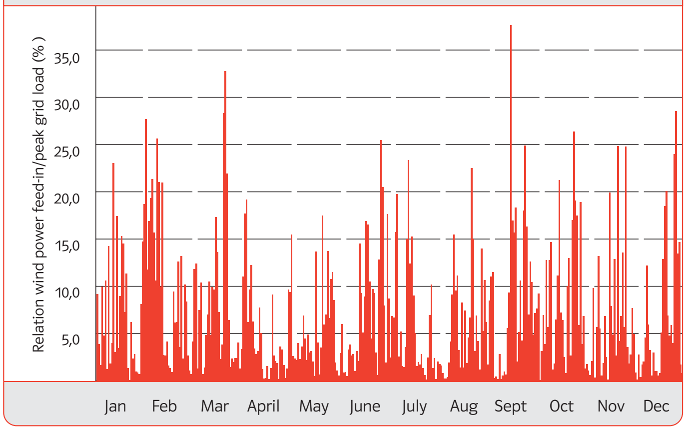
The level of wind power feed-in fluctuation depends on the prevailing wind strength. In 2004, wind power production in the E.ON area varied in real terms between zero and a third of the daily peak grid load (FIGURE 3).

The maximum monthly wind power feed-in in 2004, which stood at 1,182 million kWh in February, was almost twice as high as the minimum feed-in of 646 million kWh in July (FIGURE 4). The extreme fluctuations in wind power feed-in due to the weather are also evident from a comparison of the individual months against the same periods during the previous year. This is especially evident for the months of February and September.

The weather situation 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 to meeting electricity consumption demand is correspondingly low.

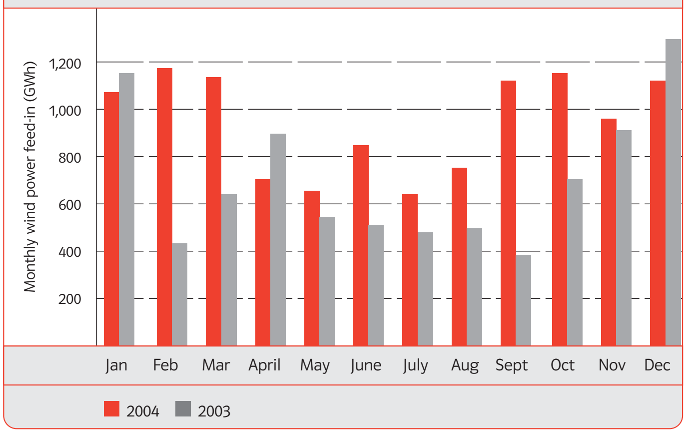
3. Wind power feed-in in the E.ON control area

2004 between 0.2 and 38% of daily peak grid load



4. Wind power feed-in

in the E.ON control area in 2004



Annual curve

The annual curve is a traditionally used tool in energy management, e.g. it can help to characterise plant operational behaviour. To produce the annual wind feed-in curve the in feed capacity is calculated for every quarter hour of the year, this is then reproduced on a graph, from left to right, in ascending order. If we look at any point along the curve, the value on the horizontal axis shows during how many quarter hours in the year the wind farms fed in at least the capacity shown on the vertical axis. Feed-in was below this level for the remainder of the year.

5. Annual curve

Wind power feed-in 2004 in the E.ON control area

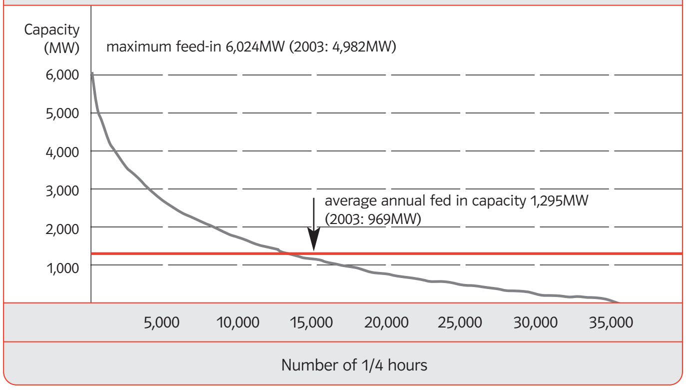
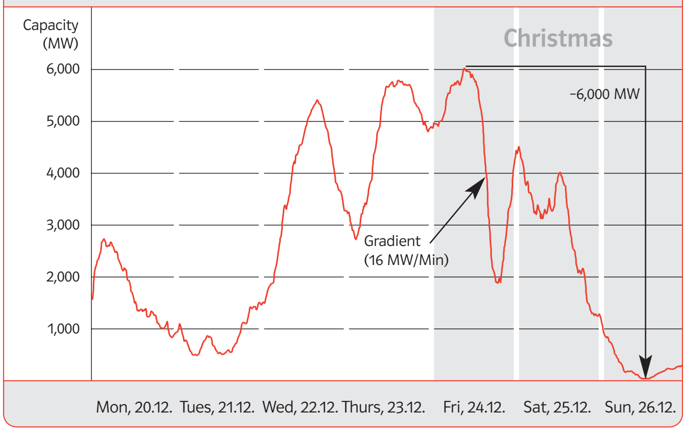


FIGURE 5 shows the annual curve of wind power feed-in in the E.ON control area for 2004, from which it is possible to derive the wind power feed-in during the past year:

1. The highest wind power feed-in in the E.ON grid was just above 6,000MW for a brief period, or put another way the feed-in was around 85% of the installed wind power capacity at the time.
2. The average feed-in over the year was 1,295MW, around one fifth of the average installed wind power capacity over the year.
3. Over half of the year, the wind power feed-in was less than 14% of the average installed wind power capacity over the year.

6. Short-term drop

in wind power feed-in over Christmas 2004



The feed-in capacity can change frequently within a few hours. This is shown in FIGURE 6, which reproduces the course of wind power feed-in during the Christmas week from 20 to 26 December 2004.

Whilst wind power feed-in at 9.15am on Christmas Eve reached its maximum for the year at 6,024MW, it fell to below 2,000MW within only 10 hours, a difference of over 4,000MW. This corresponds to the capacity of 8 x 500MW coal fired power station blocks. On Boxing Day, wind power feed-in in the E.ON grid fell to below 40MW. Handling such significant differences in feed-in levels poses a major challenge to grid operators.

Guaranteed wind power capacity below ten percent – traditional power stations essential

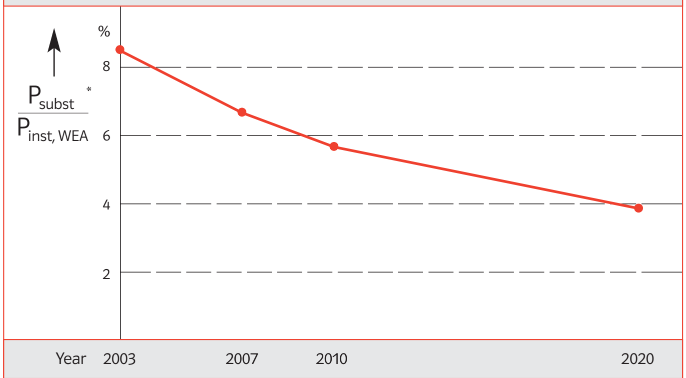
In order to also guarantee reliable electricity supplies when wind farms produce little or no power, e.g. during periods of calm or storm-related shutdowns, traditional power station capacities must be available as a reserve. This means that wind farms can only replace traditional power station capacities to a limited degree.

An objective measure of the extent to which wind farms are able to replace traditional power stations, is the contribution towards guaranteed capacity which they make within an existing power station portfolio. Approximately this capacity may be dispensed within a traditional power station portfolio, without thereby prejudicing the level of supply reliability.

In 2004 two major German studies investigated the size of contribution that wind farms make towards guaranteed capacity. Both studies separately came to virtually identical conclusions, that wind energy currently contributes to the secure production capacity of the system, by providing 8% of its installed capacity.

7. Falling substitution capacity

The more wind power capacity is in the grid, the lower the percentage of traditional generation it can replace.



Source: Institut für Elektrische Anlagen und Energiewirtschaft, RWTH Aachen
* P_{subst}: power station capacity that can be substituted by wind power
$P_{inst, WEA}$: installed wind power capacity

As wind power capacity rises, the lower availability of the wind farms determines the reliability of the system as a whole to an ever increasing extent. Consequently the greater reliability of traditional power stations becomes increasingly eclipsed.

As a result, the relative contribution of wind power to the guaranteed capacity of our supply system up to the year 2020 will fall continuously to around 4% (FIGURE 7).

In concrete terms, this means that in 2020, with a forecast wind power capacity of over 48,000MW (Source: dena grid study), 2,000MW of traditional power production can be replaced by these wind farms.

Wind power forecasting is critical to system integration – E.ON Netz constantly improves forecasting methods

Adequate quantities of electrical energy cannot be commercially stored. This means that exactly the same amount of energy must be fed into the grid as is taken out. If the amount fed in differs from the amount removed, this can cause faults or even failure of the supply, as occurred in 2003 in the USA, Italy, Sweden and Denmark.

The transmission system operators must always ensure a balance in their control areas between generation and demand.

Generation in traditional power stations can be easily controlled in line with demand. As a result, in the past it was only the time pattern of energy removed from the grid that was relevant to the balance between generation and demand. Due to regular consumption behaviour, this energy removal can now be forecast with a high degree of accuracy. However, the increased use of wind power in Germany has resulted in uncontrollable fluctuations occurring on the generation side due to the random character of wind power feed-in. This significantly increases the demands placed on the control balancing process.

So that a stable grid operation is possible despite the high fluctuations of wind power feed-in, the most accurate forecasts possible of expected feed-in are needed. E.ON Netz was the first transmission system operator to use a complex forecasting system, which it developed with the Institut für Solare Energietechnik, ISET. This forecasting takes place in three stages.

1. Weather forecast as basis

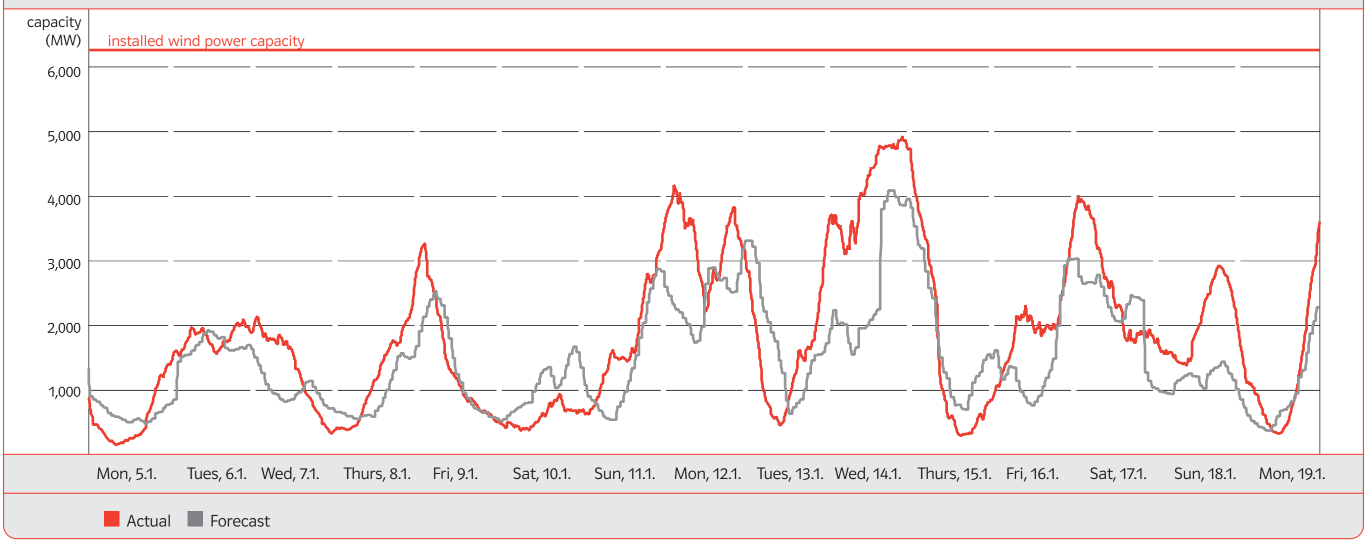
The wind capacity forecast is based on a forecast of wind speed and direction produced by the Deutsche Wetterdienst (DWD), and on other meteorological parameters at 16 (rising to 30) selected reference locations within the E.ON grid area.

2. Transformation to local conditions

The data supplied by DWD cannot be used directly for the feed-in forecast at the reference location. It must first be adapted locally to the specific circumstances of the wind farms, eg, the DWD data currently exists for a height of 10m above the ground and the wind farm turbine rotors, at the reference locations, can turn at heights of over 100m. As a result, the DWD data must be converted using a three-dimensional atmospheric model before it can be processed.

8. Limited accuracy of the weather forecast

limits the accuracy of the wind power forecast – example: E.ON control area, 5 to 19 January 2004



Dr.-Ing. Martin Hoppe-Kilpper, Division Manager for Information and Energy Management, ISET [1]:
"It is vital for the integration of wind power into the supply system that anticipated wind power feed-in should be forecast as accurately as possible. We have been working continuously for years with E.ON Netz GmbH on the ongoing development of our joint forecasting system, in order to further increase its accuracy and consequently to minimise the wind power-induced reserve capacity required. Through our cooperation with E.ON Netz we have managed to set standards that are exemplary in global terms."

3. Determining the wind power feed-in for the E.ON control area

Feed-in forecasts for the reference locations and the entire control area are calculated using artificial neuronal networks (ANNs). The ANNs are continuously "trained" on the basis of past experiences. This allows the continual improvement of forecasting quality.

The methods and accuracy of the E.ON Netz forecasting system has set new standards around the world, and it is now also used by other German transmission system operators. Despite the high forecasting accuracy already achieved, E.ON Netz, along with ISET and the other German transmission system operators, is working continuously on further improvements to the quality of the forecasts. In addition, E.ON Netz is involved in international exchanges of experience, e.g. with Japan and Australia, through which it hopes to gain further opportunities to better the system at an early stage. Cooperation with other companies within the E.ON Group such as E.ON UK and E.ON Nordic, both of whom are wind farm operators who are intensively involved in developing their forecasts, is of particular importance.

A key factor in the accuracy of the feed-in forecast is the quality of the weather and wind forecasts, as all the other forecasting stages rely on this data. There are clearly natural limits to the quality of the wind power forecast (FIGURE 8). However, the German Meteorological Service is currently working on improving wind forecasting, in a research project covering a number of years.

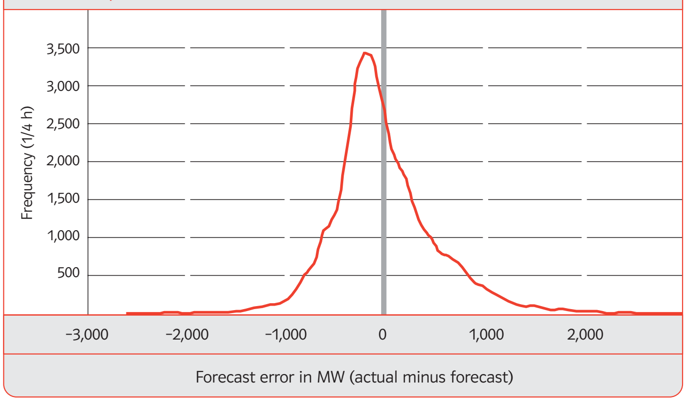
FIGURE 9 shows the frequency distribution of the forecast error. In 2004, the maximum negative forecast error for the E.ON control zone, ie the value by which the actual feed-in was below the forecast value, stood at -2,532MW, while the maximum positive forecast error stood at 3,999MW. All data is based on the 8 hour forecast of the previous day.

Online logging

For operational reasons, and in order to implement what is termed the horizontal equalisation scheme between the German transmission system operators, E.ON Netz must be aware at all times of the current actual wind power feed-in in the grid area. With over 7,600 wind farms within the grid area, it's not possible to equip all plant with the necessary measuring equipment and to continuously log the data centrally. As a result, an online model has been developed jointly with ISET. This calculates the current total feed-in of the wind farms from the feed-in data measured online at 36 representative wind farms (installed capacity 1,330MW), with the aid of a transformation algorithm.

9. Frequency distribution of the forecast error

for wind power feed-in 2004 in the E.ON control area



[1] Dr. Hoppe-Kilpper has changed position and is meanwhile working for the Deutsche Energie-Agentur (dena).

Wind power "equalisation" – Reserve capacity needed for safe supply

Under the Renewable Energy Act (EEG), all electricity traders who supply consumers in Germany must cover a specific proportion of their sales with electricity that is promoted under the Act. In 2004, the EEG quota stood at 8.1%. Under the EEG provisions, the transmission system operators supply this electricity, and at the present time around two thirds is generated by wind energy. It is difficult for traders to include the "real-time delivery" of the EEG electricity in their procurement planning. Until such time as the market mechanisms necessary for transfer of the EEG feed-in to traders at short notice have been set up, transfer to traders (vertical power equalisation) is based on previously determined supply profiles. The conversion of the actual wind power generation into safe supplies by the transmission system operators is called "EEG equalisation". In simple terms, the process can be described in two stages:

Prof. Dr.-Ing. Ulrich Wagner, Chair of Energy Management and Applications Engineering at the Technische Universität in Munich:

"Balancing out variations in capacity brought about by fluctuating wind power feed-in and possibly power station failures is a key duty of the transmission system operators. The increased use of wind power in Germany has already led, over the past few years, to a marked increase in reserve power requirements. Given the anticipated further increase in capacity, it is already evident today that wind power is set to become the leading factor of influence as regards control and reserve capacity requirements in the future."

1. Day-ahead equalisation

The transmission system operator first of all produces an EEG feed-in forecast for the next day. Based on this forecast, it is possible to balance out the difference between the supply to the traders and the forecast value through appropriate trades. If the forecast is higher than the EEG supply, then the difference for the hour in question on the following day is sold. If the forecast value for the hour in question is below the value of the EEG delivery to the traders, then the difference is bought in (FIGURE 10).

Since the anticipated power feed-in according to the EEG must be taken into account in the resource scheduling of the traditional power stations, EEG equalisation is based on the 8a.m. forecast of the previous day. This 8a.m. forecast is also especially important because energy markets close for short-term spot market transactions at midday on the previous day.

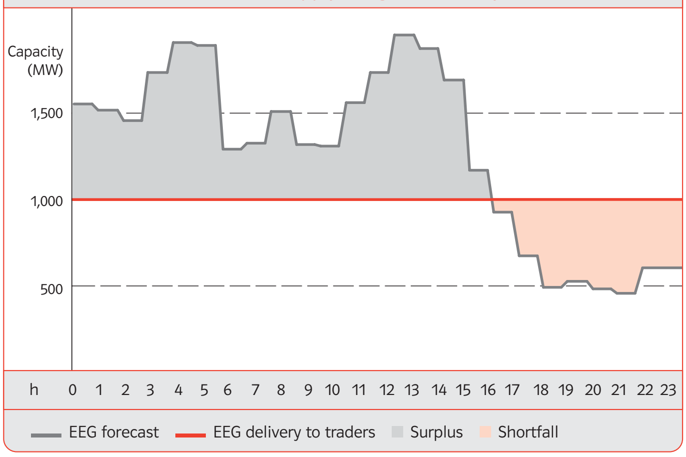
2. Equalisation during the day

During a second stage, the difference between the forecast produced on the previous day and the actual EEG feed-in must be balanced out (FIGURE 11). This equalisation is fundamentally undertaken by using reserve capacity, for which the transmission system operators must have guaranteed continuous full availability in advance. The extent of the equalisation during the day is largely determined by wind power feed-in forecasting error.

With the continued expansion of the use of wind energy in Germany, demand for standby reserve capacity will continue to rise, and will increase around fivefold by 2020.

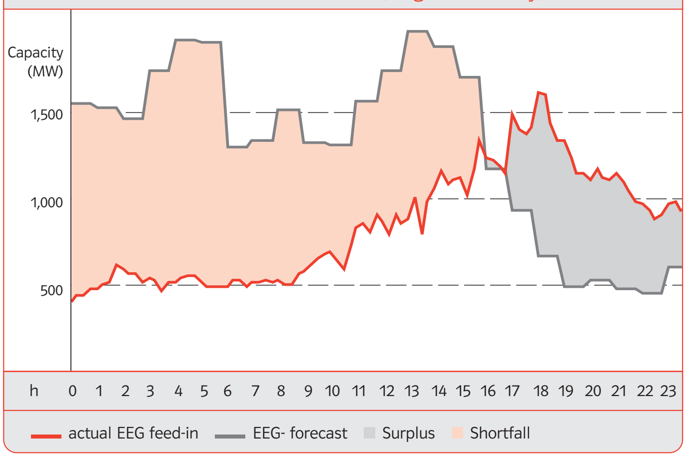
10. EEG equalisation: First stage

Day-ahead equalisation: equalisation of the difference between the forecast and continuous supply (diagrammatically)



11. EEG-Equalisation: Second stage

Equalisation during the day: equalisation of the difference between the actual EEG feed-in and the forecast (diagrammatically)

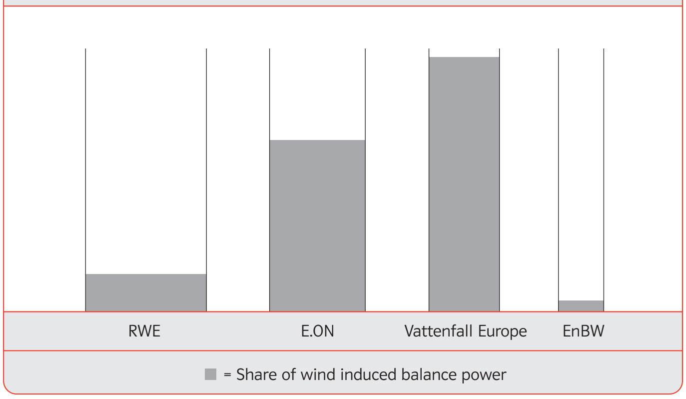


Prof. Dr.-Ing. Hans-Jürgen Haubrich,
Institut für Elektrische Anlagen und Energiewirtschaft,
RWTH Aachen:
"Through the immediate equalisation of wind power feed-in throughout Germany, the EEG amendment has managed to remove the former distortions suffered by grid customers in very windy areas and to reduce the overall wind power induced reserve capacity demand. The transmission system operators have achieved technical implementation so quickly that online exchange was able to go live as early as 1 September 2004."

2004 Renewable Energies Act (EEG) amendment allows for a fairer financial burden sharing among electricity consumers

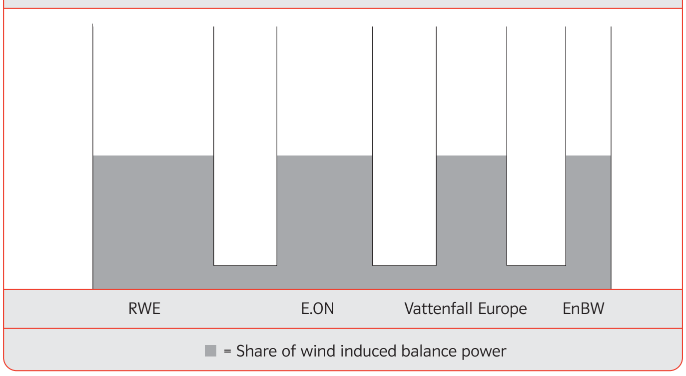
12.a Load distribution with wind power control

Formerly: Uneven distribution of wind power control costs



12.b Load distribution with wind power control

Now: Online equalisation – all grid operators are involved in wind power control on the basis of their final consumer sales



The costs of the EEG equalisation, in particular those for the procurement of reserve capacity, represent a significant cost factor for the transmission grids, which increasingly affects the level of the grid utilisation costs.

Before the amended EEG came into force on 1 August 2004, the reserve capacity requirement in the four German control zones also differed significantly due to the uneven distribution of the wind farms in Germany. The control areas of E.ON Netz and Vattenfall Europe Transmission were most seriously affected, since their proximity to the coast means that they had more wind power and consequently a very high reserve capacity demand, coupled with high costs.

E.ON Netz lobbied intensively for this drawback to be eliminated, since it impacted on grid customers in the control areas where a great deal of wind power is used. The legislator took this into account in its amendment last year to the Renewable Energy Act. The EEG now provides for the "immediate" equalisation of wind power feed-in between the transmission system operators (FIGURES 12.a and 12.b).

All transmission system operators are now obliged to become involved in the equalisation of wind power fluctuations on the basis of their share of electricity sales in Germany.

Thanks to a high level of cooperation between the transmission system operators, it proved possible to achieve the speedy technical implementation of "online equalisation" as early as 1 September 2004, just a month after the Act came into force.

Wind power needs an infrastructure – E.ON Netz presses ahead with grid expansion

Due to the specific geographic situation in Germany, one decisive factor in relation to the further expansion of wind energy use will be the capacities of the electricity grids. Today, the grids in some northern areas of Germany where there is high wind power feed-in,e.g.Schleswig-Holstein and Lower Saxony are already approaching their capacity limits. When the wind is strong, they are unable to take up any additional wind power without prejudicing the safety of the supply.

The reason: up to now, electricity supplies in Germany have largely been decentralised, with power stations having been built across the country as close to consumers as possible. This 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 flowed in one direction and only across relatively short distances. Consequently the grids served exclusively for supply purposes. This has changed with the boom in wind energy. An increasing number of wind farms are being built primarily in coastal and relatively sparsely populated areas of low consumption in northern Germany. In periods of strong wind they generate more energy than the area in question consumes at the same time. During such times, the grid serves to transport the wind power southwards over long distances.

The example of Schleswig-Holstein: Surplus wind power on windy days

Whereas total electricity consumption (grid load) in North Friesland is between 40MW (low load) and 120MW, wind farms with a total production capacity of over 500MW are installed in the area. Consequently, even at periods of high consumption, around four times as much electricity is generated by wind power on windy days than is used by customers

This surplus wind power has to be transported to consumers over long distances. The size and operation of the grids must be altered to cope with this requirement, with the primary objective of avoiding overloading lines and the resulting losses of supply.

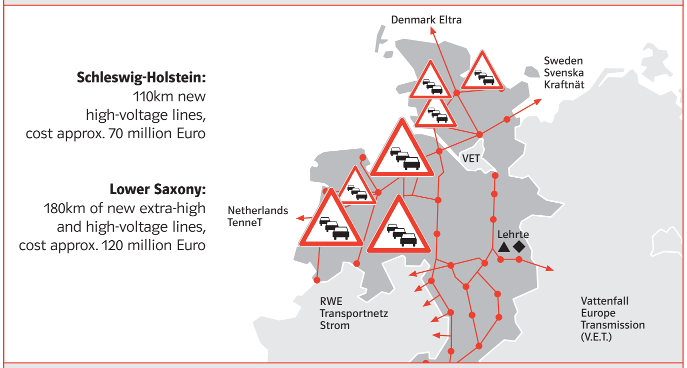
E.ON Netz took on the task of eliminating wind-related congestions at an early stage

The Renewable Energy Act obligates grid operators to immediately eliminate wind-related congestion via appropriate expansion measures. As soon as the EEG came into force in 2000 E.ON Netz GmbH, despite serious planning difficulties, completed the necessary estimates of further wind power expansion together with wind power associations and politicians. These were then compared with available grid capacities. As a result:

- At the present time, E.ON Netz is planning around 110km of new 110kV HV lines in Schleswig-Holstein, the cost of which is estimated at €70 million, to remedy wind-induced congestion.
- Approximately 180km of HV and extra-HV lines are being planned in Lower Saxony, including for the first time a new wind-related extra-HV route in the Oldenburger Münsterland, from Ganderkesee to St. Hülfe in the vicinity of Diepholz. The estimated cost for the line construction in Lower Saxony is around €120 million (FIGURE 13).

13. Wind power induced grid congestions

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



Expansion in the extra-high voltage grid – 2,700km needed by 2020

The dena grid study identified a need for expansion of over 2,700km by the year 2020 in the extra-HV German grid alone. It should be possible for around a third of this, over 800km, to be achieved through using existing power lines. This leaves just under 1,900km to be expanded using new power lines, to include the expansion in Oldenburger Münsterland described above. This grid expansion requirement is not restricted to the coastal regions. In fact the whole of Germany will be affected in the future. The dena grid study estimates the costs of this wind power-related grid expansion at over €3 billion by 2020.

Further expansions of the subordinate HV and medium-voltage grids are likely to be needed in addition to the expansion requirements for the extra-HV grid, since this is where the greater proportion of the onshore wind farms are connected.

The wind power induced grid expansion measures already introduced, coupled with the prospect of a significant further expansion requirement, have led to intensive discussion on technical grid capacity investigations and the actual technical design of the necessary lines.

Loads on equipment: keeping up with the state of the art

E.ON Netz has a considerable interest in the optimum exploitation of existing grid capacities and thus in restricting investments to what is necessary. At the same time, compliance with the state of the art is necessary, to avoid jeopardising supply safety.

E.ON Netz is currently investigating ways of further developing the state of the art, in the light of the wind power induced transmission challenges. The objective is to acquire sufficiently secure findings in relation to the use of new technologies. An attempt is being made, in scientifically monitored field tests, to ascertain to what extent the transmission capacity of parts of the grid can be increased under certain weather conditions and using innovative technologies. The following points in particular must be noted:

- Circuit load limits must be based on the entire equipment chain (conductor ropes, but also switching devices, converters, transformers in the substations).
- Grid protection systems must be capable of distinguishing between faults and wind power induced, temporarily increased loads, so that areas of the grid that are at risk can continue to be safely shut down in the event of a fault.
- Generally accepted operational parameters must be followed. Otherwise E.ON Netz might be exposed to liability in the event of loss of supply.

Overhead lines or underground cables: keeping grid expansion costs to a minimum

When planning the current grid expansions, E.ON Netz examined closely whether underground cables were an option. The technology would essentially already be available. However, the use of cables is not advisable, for the following reasons:

- Underground cables in the extra-HV grid (380/220kV) are more expensive than overhead lines by a factor of 7 to 10, and even in the HV area (110kV), the difference in cost is still a factor of 2 to 3.
- Failure times of underground cables in the event of problems (component faults, damage due to overground work) are significantly higher than in the case of overhead lines.
- In the HV and extra-HV grid, even laying underground cables encroaches on the countryside.

Legally, E.ON Netz is required to make the transmission grid available in the most cost-efficient manner possible. Since overhead lines are the most economically efficient solution, these will be used during the requisite grid expansion.

E.ON Netz is seeking to expand the grid as quickly as possible

E.ON Netz is concerned to complete the requisite grid expansion as quickly as possible. Reliable information on the evolution of consumption and production in the individual grid areas is a key input parameter for grid expansion planning. Sufficiently reliable information of this kind in relation to the evolution of wind power capacities is not generally available. The following are required in order to produce wind power expansion forecasts for specific areas:

- Binding selection of preferential areas for wind power, in order to prevent uncontrolled plant expansion.
- Binding definition of the admissible area density of the installed wind power capacity, expressed in hectares per megawatt installed wind power.
- Reliable forecasts of project realisation likelihood and timings.

In the past, these criteria have frequently been unavailable, leading to uncertainties in expansion planning.

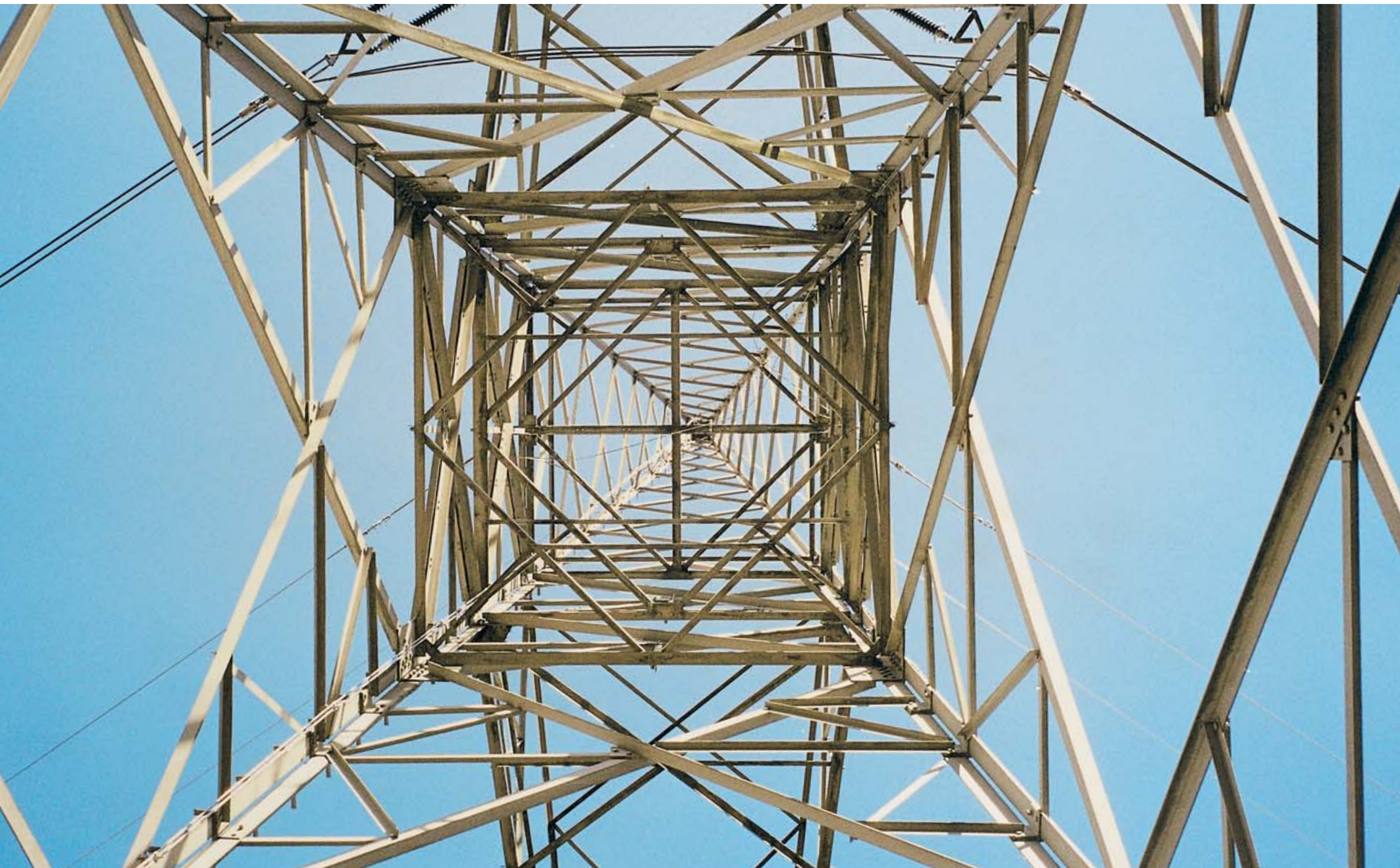
In order to speed up the actual power line planning process, E.ON Netz uses ultra-modern technology, such as laser scanning, during the planning phase. This makes it possible to complete the survey work needed for power line planning through the use of helicopters, with previously unheard-of speed and precision, and thereby to reduce the length of the planning period.

The length of the necessary approval procedure represents the main obstacle to speedy realisation of the planned line construction work. For this reason, E.ON Netz, together with the Government of Schleswig-Holstein, commissioned an opinion from the well-known energy lawyer Prof. Peter Salje, analysing the lengths of the process and how these can be reduced. The investigation shows that in the present legal situation, the process (including court proceedings) is likely to take around 7 to 10 or more years. The possibility of implementing specific ways of speeding things up, e.g. reducing the length of the process, are currently being examined in a close dialogue with politicians and lawyers.

E.ON Netz guarantees grid safety through generation management

The large rapid expansion of the installation of wind farms in Schleswig-Holstein means that on windy days, the grid capacities of regeneratively generated electricity are entirely exhausted. Although E.ON Netz instituted grid expansion measures at an early stage, it must be assumed that it will be several years before the planned power lines are built. In order to be in a position to connect further renewable energy power production plants before the grid expansion is completed, E.ON Netz has developed what is referred to in generation management as a transitional solution. Generation management involves the intermittent reduction of the power fed in by the plants, in order to protect grid equipment such as overhead lines or transformers from feed-in-related overloads, thereby avoiding supply failures.

In mid 2003, E.ON Netz implemented generation management in Schleswig-Holstein, together with E.ON Hanse. Plants with a total capacity of at least 700MW (around one third of the total EEG capacity installed in Schleswig-Holstein) are currently involved. In 2004, generation management had to be introduced in Schleswig-Holstein 17 times. The duration of the feed-in restrictions in specific areas was between 30 minutes and 12 hours. Feed-in to the wind farms had to be reduced to levels of between 60 and 0%. The associated total losses of income for wind farm operators were low, although individual operators were affected to very differing degrees.



In future, in parallel with the further expansion of wind power, generation management is likely to be used increasingly frequently. After initial difficulties experienced by operators due to the technical implementation of generation management, virtually all those involved have now accepted it.

The increasing exhaustion of the capacities of the high-voltage grids by EEG electricity has also meant the introduction of generation management in Lower Saxony. In the first half of 2005, after the necessary technical and contractual criteria were met, in cooperation with the regional suppliers Avacon and EWE, and the plant operators, generation management was implemented in the first areas within Lower Saxony. This has only been in areas that have been seriously affected by grid congestion, and other areas will follow, as necessary, as expansion progresses.

Generation management makes it possible to guarantee a safe electricity supply, whilst ensuring optimum use of the grids for the take-up of EEG electricity.

Nevertheless, generation management is only a transitional solution. As soon as the necessary grid expansion measures have been implemented in the individual areas, the plant affected will be released from generation management again.

Topical information in relation to generation management is available at www.eon-netz.com.

How generation management functions

Based on grid calculations, the E.ON grid has been divided up into 10 regions in Schleswig-Holstein (25 regions are envisaged in Lower Saxony). Every inadmissible load on equipment is automatically forwarded to the grid management centre of E.ON Netz GmbH. Following identification of the affected region, a signal is sent to the wind farms feeding in electricity in this region or to other decentral generation plants. 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.

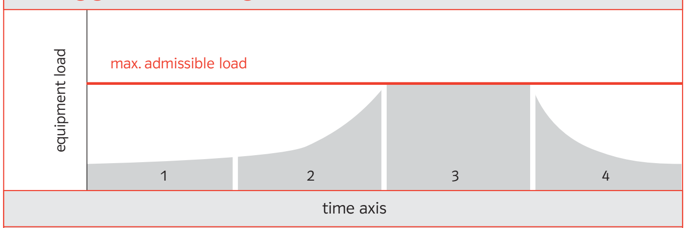
The wind farm operators are responsible for the demanded reduction in the feed-in power. They must ensure in technical terms that the power reduction signals are converted by the plant management system. They therefore make an essential contribution towards maintaining a safe supply.

Direct power control or even switching off 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 through a signal sent to the respective wind farm management system.
(FIGURE 14)

14. Equipment load

during generation management



Phase 1: Equipment load within admissible limits, grid situation not critical
Phase 2: Equipment load reaches critical level, supply safety at risk
Phase 3: Signal sent to participating wind farms, demanding feed-in reduction
Phase 4: Critical grid situation has ended, feed-in restriction lifted

Wind power increasingly affects market development and power flows in Europe

Feed-in from wind farms in Northern Germany is now occasionally so high that, despite the use of generation management, it can only be coped with through significant intervention into grid and market development. Neighbouring European transmission system operators also are increasingly affected.

• Special switching measures are needed in order to guarantee supply

On very windy days, normal operation of the transmission grid is sometimes no longer possible. Special switching measures are needed, in order to prevent wind power-induced grid overloads and consequently supply failures occurring. These special measures primarily affect Northern Germany, but they also affect Northern Bavaria, due to the transport of wind power from Eastern Germany.

• Interventions in international electricity trading and the power station park

Wind power feed-in and the measures necessary for its integration need increasingly frequent intervention in international electricity trading, e.g. along the Danish-German border. If the grid on the German side is exhausted with wind power, then transport capacities for cross-border trading transactions must be reduced accordingly.

In some cases it is also necessary to intervene in traditional power station generation and to reduce the feed-in of individual power stations, in order to maintain supply safety. However, such interventions generally lead to the shift of power generation to less efficient units.

• Impact on neighbouring grid operators

Neighbouring European transmission system operators are also increasingly affected by the high wind power feed-in in Germany. The reason for this is that power always flows within the grid according to the laws of physics and seeks out the route of lowest electrical resistance. As a result, sometimes a significant proportion of the wind power infed in Northern and Eastern Germany flows in a loop through the grids of the neighbouring countries of the Netherlands, Poland and the Czech Republic, where it leads to significant loads on the operating resources.

The wind power-induced impact of international electricity trading and load flows through third party grids makes it clear that the further expansion of wind farms in Germany is no longer possible nationally in isolation, but that we must also consider the effects at European level.

Wind farms must also contribute towards stable grid operation

In Northern Germany, the continued expansion of wind energy will make it increasingly difficult to guarantee supply stability in the future. This is due to a number of specific factors:

- There is a concentration of wind farms in this particular region;
- Many of these wind farms are older technology and less able to contribute to grid stability;
- There could be little conventional generation in the future in this area leading to an unbalanced situation in terms of generation types;
- Wind power in Germany is given priority over conventional generation in terms of access to the grid.

Even simple grid problems can lead to significant failures in wind power production.

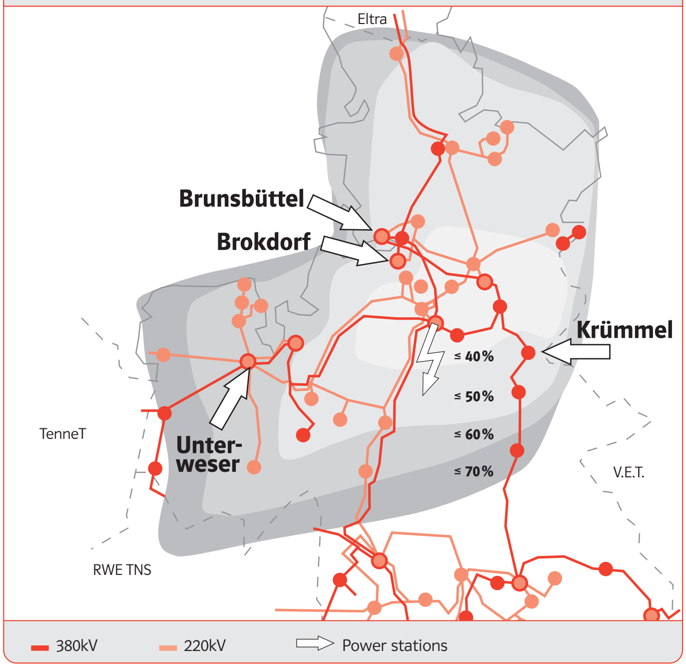
Large thermal power stations do not disconnect from the grid even following serious grid failures, instead they generally trip into auxilliary services supply and until then, "support" the grid. Wind farms, however, have so far disconnected themselves from the grid even in the event of minor, brief voltage dips. Experience shows that this can lead to serious power failures:

- On 29 January 2004, a two-phase line fault occurred in the 220kV grid in the Oldenburg region and resulted in splitsecond-long voltage dips in the region concerned. This produced a sudden loss of around 1,100MW of wind power feed-in.
- On 15 September 2004, a crane caused an earth fault on an extra-HV line in Hamburg. The resulting brief voltage dip of a few tenths of a second meant that approx. 600MW of regenerative power disconnected from the grid in the Hamburg region.

In order to prevent further wind power expansion bringing a serious risk to supply safety, manufacturers and operators must technically ensure that in the event of a fault, wind farms also contribute to the avoidance of critical grid situations.

15. Potential gradient area

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



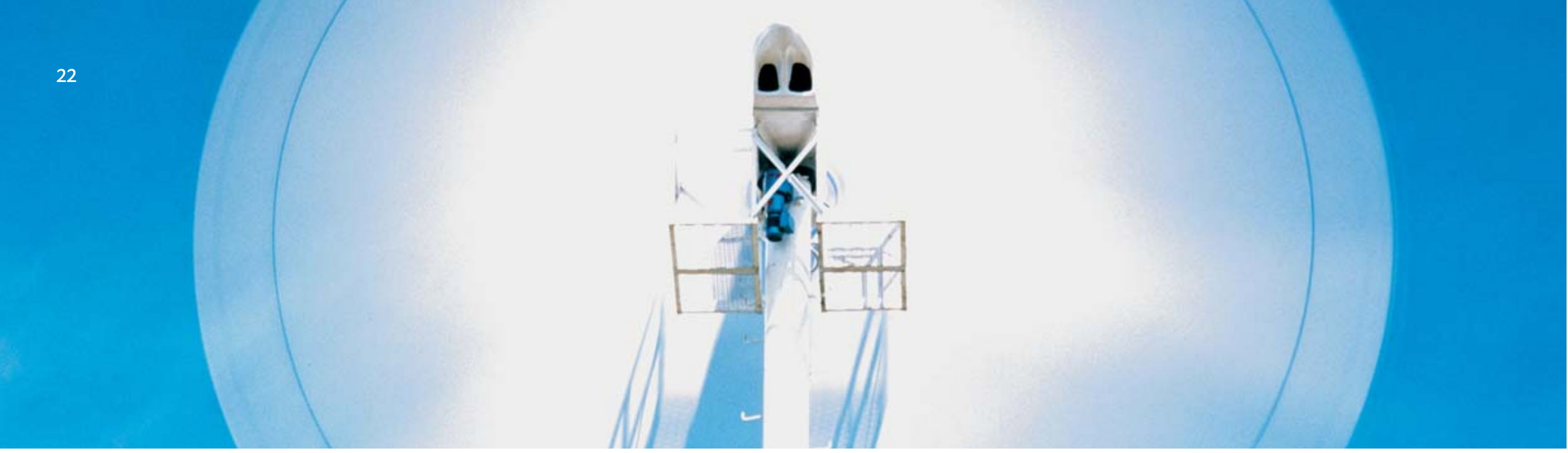
Failure of wind power production in the event of grid faults jeopardises supply safety

As an example, FIGURE 15 shows the voltage dip as a percentage of grid voltage in the event of a fictitious three-phase fault close to the Dollern substation.

In this specific case, the grid voltage could briefly fall by over 20%. This could result in the sudden failure of almost the entire wind power supply in this area. This could cause problems for the reserves provided by Integrated European Transmission System.

Idle power feed-in critical to stable grid operation

Wind farms must contribute to grid stability even during normal grid operation. The provision of idle power is especially important. For physical reasons, it is necessary to feed in idle power in line with demand and distribute it over the entire grid as this will maintain a stable network voltage. If there is no idle power, or if the distance between the feed-in points is too great, then the voltage situation can deteriorate, and may even cause a voltage collapse in the grid.



E.ON Netz grid connection rules – both exemplary and critical to safe grid operation

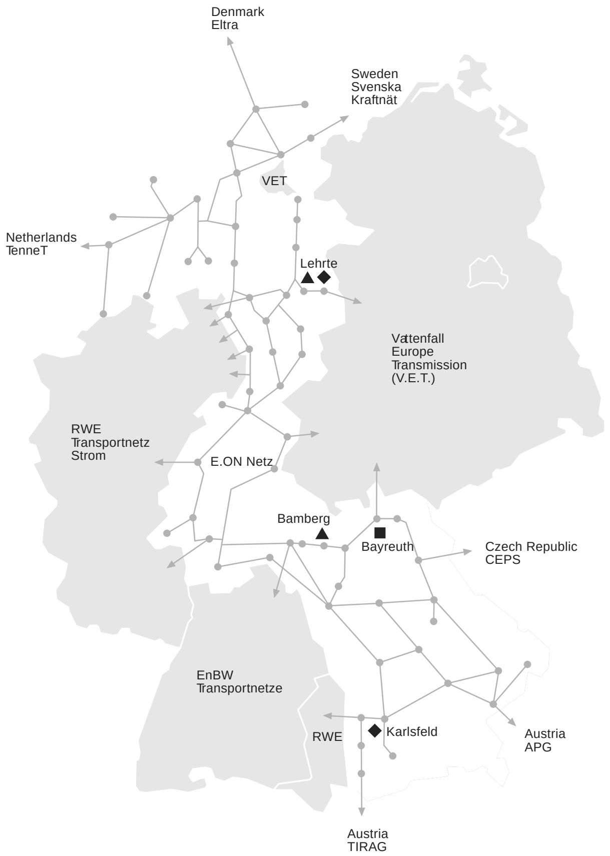
When the German Renewable Energies Act came into force in 2000, E.ON Netz immediately laid down new grid connection rules with concrete specifications for the behaviour of wind farms during normal operation and in the event of faults. In 2003, these rules were updated, with the cooperation of the plant manufacturers, to take account of operational experience to date. Their main content has also been reproduced after recommendations from the Verband Deutscher Netzbetreiber (VDN) for the operational behaviour of decentral production plants.

Although the operational behaviour of wind farms has since been increasingly directed towards grid stability, traditional power stations are vital in providing grid support and in maintaining system stability.

By the 2010 consistent adherence to and implementation of the grid connection rules is expected to temporarily relieve the situation and to bring a reduction in wind power feed-in failures in the event of grid problems.

However, the grid stabilising effect of traditional power stations would be lost as they are shut down for a variety of reasons, such as age or an increase in other forms of generation. At the same time, in ten years time there will still be a large number of older wind farms in Germany feeding into the grid, which do not have the necessary grid supporting features. There is therefore a risk that even simple grid problems will lead to the sudden failure of over 3,000MW of wind power feed-in. In this case, the reserves maintained in the Integrated European Transmission System, in order to cope with problems, would no longer be adequate to safely tackle such failures.

At the present time, it is not known how to confront this risk. Investigations must be made to determine to what extent the situation can be improved by replacing turbines at older wind farms or by introducing additional technical equipment to support the transmission system in the event of faults, or whether additional feed-in restrictions measures will be needed for old plants.



■ Corporate Headquarter
▲ Operational Center
◆ Main Control Center

● Substation

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