INTEGRATION OF WIND POWER INTO DISTRIBUTION NETWORKS

Hans ROMAN
envia Verteilnetz GmbH – Germany
hans.roman@envia-netz.de

Stefan DORENDORF
EON edis Netz GmbH – Germany
stefan.dorendorf@eon-edis-netz.com

ABSTRACT

The political promotion of renewable energies in Germany has led to a strong increase in the generation capacity especially by wind energy conversion. Therefore, the capacity of MV and HV networks in windy regions of North and Central Germany will have run out in a few years. In locations with strong winds and low loads, distribution networks feed energy back into the transmission network in considerable amounts, with the result that bottlenecks may occur.

This paper describes a possible way to avoid problems concerning both the security and the stability of the supply system.

INTRODUCTION

With the promulgation of the EEG (law on renewable energies), the German government is striving for covering an essential portion of the electric power demand on the basis of renewable energies. In 2020, a total of 20 % of the electric energy shall be produced from regenerative energy sources. The strong financial support given by the state to promote renewable energies has led to a considerable increase particularly in the number of wind power plants (WPP) in Germany.

In 2006, a total of 18,054 wind turbines presenting an installed capacity of 19,299 MW were connected throughout Germany [1]. Thus, about one third of all WPPs installed all over the world are found in Germany. About 85 % of all turbines are installed in the northern federal states. By the year 2030, up to 25,000 MW shall be installed off-shore according to the German government's intentions [2]. The most challenging task to be solved in the future is - from the network operators' point of view - to integrate the already existing generating systems and also those which will still be put into operation into the systems available at present.

The high portion of decentralized generating capacity mainly entails upgrading the networks to increase the transmission capacities. By then, it is absolutely necessary to safely master those influences which come about by the wind, such as risk of exceeding the network rating and greatly changing power flows. For this, appropriate measures will have to be taken.

CURRENT SITUATION

With a surface area of 37,800 km² and 26,060 km², respectively, both the E.ON edis Netz GmbH company and the envia Verteilnetz GmbH company are large regional network operators. Their networks cover two thirds of the surface of East Germany with high portions of network regions whose economic development is below average, thus having a low energy demand.

Particularly in the north of East Germany (Mecklenburg-West Pomerania), there are supply areas with a population density of only 25inhabitants/km^2, thus being some of the most sparsely populated regions in Europe.

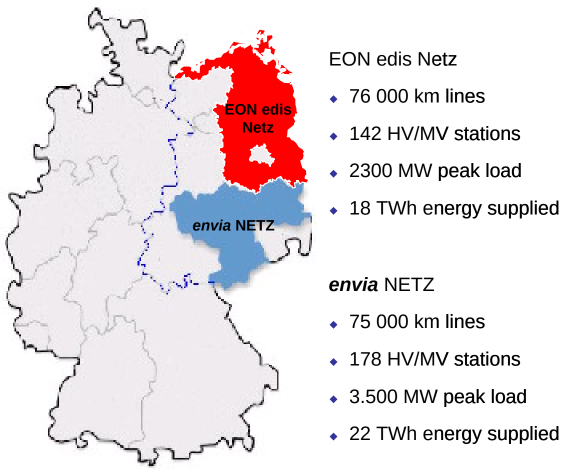

Fig. 1: Location of the network regions described in Germany

As per December 2006, renewable power plants (RPP) with an installed capacity of a total of about 6,700 MW are connected in the network regions of both companies. More than 80 % of the installed capacity is produced by wind turbines. Furthermore, a number of RPP with an installed overall capacity of more than 9,600 MW have already been submitted. From this, the high potential for the future can clearly be seen. About 35 % of all electric energy supplied by EON edis to the end consumers is produced from regenerative energies, with this portion amounting to about 17 % for the company envia NETZ.

As far as the further development of the installed capacity supplied by wind turbines is concerned, trends indicate a slower growth rate within the country in the next years as it will become more and more difficult to find economically suitable sites where the applications will possibly be approved. In comparison, considerable offshore capacities will have to be connected to the grid from 2008 on. For this, however, further large grid connection capacities will have to be installed.

As far as the technical aspects of line operation are concerned, the power supply network develops more and more into a "disposal network". In former times, the direction of current flow was clearly from the transmission network to the distribution network. In contrast to this, it is a fact that today's network presents a higher load in the opposite direction in some regions. In Figure 2 is shown an exemplary load flow during one day.

From the balance of the curves representing „regenerative energy feeding", "current consumption" and „conventional power plants" shown in this figure fore a whole day, it can be seen that energy was fed from the distribution network of the E.ON edis back into the distribution network of the Vattenfall company (curve "Transmission to VET").

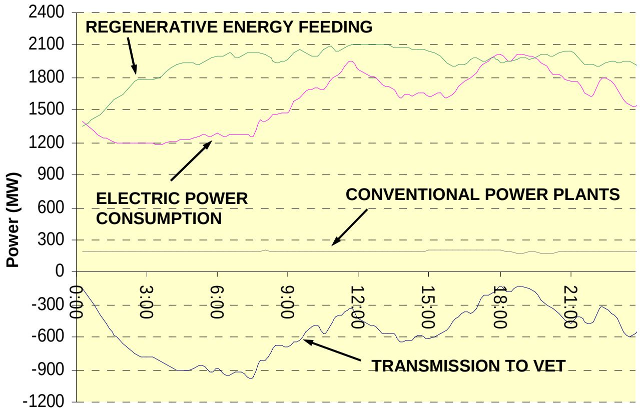

Fig.2: Load flow between transmission network and distribution network on a day with strong wind

This fact must be taken into account in the rating of the network. Bottlenecks occurring during the disposal task of the network have already become reality. In order to be able to connect more feeders, the extension of the network is imperative. Figure 3 shows the degree of the network overload. The hatched areas mark the HV network regions, which would be totally overloaded in the case of malfunction without the application of relief measures. This is the biggest part in both networks.

The extension of the 110 kV network is a real challenge. Due to the fact that both public-law and private-law authorization procedures (material security) are lengthy, also line construction measures take a lot of time.

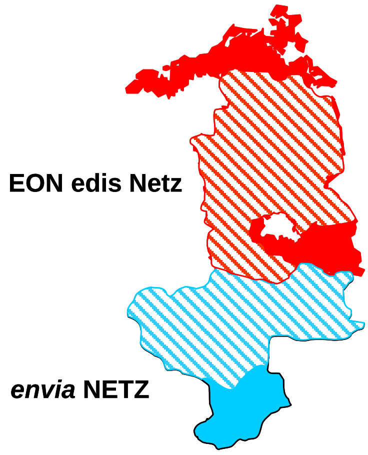

Fig. 3: „Overloaded" areas by WPP

Furthermore, bottlenecks occur only under the following conditions:

a) high feeding capacity
b) consumer load is low

Especially in the case of wind turbines, case a) seldom occurs. In the landlocked country, a total of 1,500 up to 2,000 full-load utilization hours per year are assumed. Figure 4 shows the typical utilization distribution of the rated power of a real wind power station in the landlocked country. This station does not feed any electricity into the grid for approximately 1,500 hours per year. Most frequently (2,200 h) a capacity of around 5 % of the rated power is fed into the grid, whereas the maximum output can be reached only for a few hours per year.

Watching many wind farms simultaneously, it can clearly be seen that the maximum output is never reached. In distribution networks, simultaneous values of about 90% to 95% of the maximum output is reached, with this value nearly never exceeding 80% in the case of distribution networks.

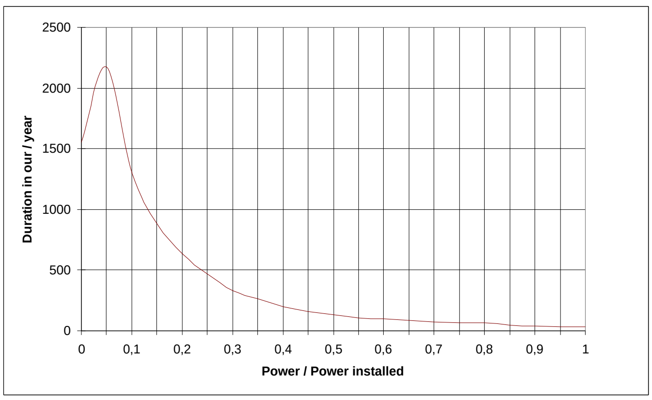

Fig. 1: Typical duration of wind feeding power in onshore areas

Therefore, high network loads have to be expected only temporarily. In order to achieve an even higher amount of wind energy supplies despite the bottlenecks, the law on renewable energies (EEG) released in 2004 lays down that

- for each EEG-Power plant (RPP) there is an obligation to supply including a device allowing the feeding capacity to be reduced in the case of a bottleneck situation, and that
- any bottlenecks have to be abolished immediately.

As it is not possible to limit the feeding capacity by technical measures in connection with the network, network security can only be guaranteed by limiting strategically the feeding capacity to the possible degree in critical situations. This shall be reached by the introduction of a network security management system.

NETWORK SECURITY MANAGEMENT (NSM)

The task of the NSM is to prevent network overload by reducing the feeding capacity. The systems consists of three main components, namely the evaluation tool allowing the set current limit values to be monitored in the network control system, the transmission path to the power plants, and the receiver located at the feeding power plant. The transmission technique chosen is the radio ripple control technique. This technique is necessary because it must be guaranteed that also a large number of smaller feeding power plants which are not directly connected to the control system can reliably be reached within shortest time and at low expenditure. The power plant is fitted with a radio ripple control receiver which transmits the lowering instructions to the control system of the power plant. The three components are shown in Fig. 5.

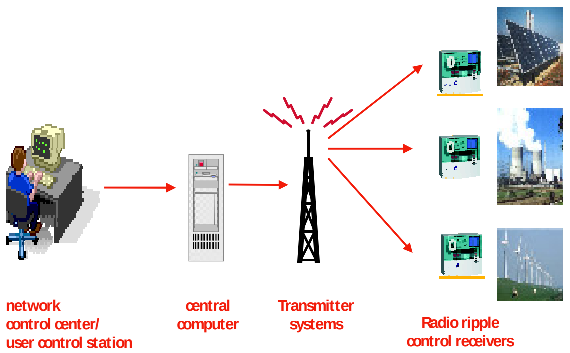

Fig. 5: Transmission path of the control instructions

The radio signals are transmitted by a long-wave transmitter (139 kHz) which can reliably reach large areas (analogously to a radio clock). Due to the low frequency, the electromagnetic field of the long wave penetrates deeply the ground, thus providing a good reception even for those receivers installed in cellars. Mainframe computers and transmitting installations as central components are operated with redundancy in order to guarantee best availability [3].

The control of the transmitting installations is integrated into the control system. Additionally, a user operating station has been set up allowing the parametrization of the receivers just as control instructions to be given. Via the structure of the telegram, the parametrization of the receivers images the following characteristic features which are necessary for the differentiated control:

- bottleneck zone (technical information)
- type of power plant (priority information)
- degree of capacity reduction (control information)

The analysis of this information allows each receiver to clearly recognise whether any lowering instructions or also the cancellation of them has to be carried out in the respective power plant. By a suitable structuring of the control telegram, several receivers can be driven simultaneously. Thus, only few telegrams and little time are necessary to achieve the desired relief effect. The receivers are inserted by the operators of RPP according to the specifications made by the network operators, who also carry out parametrization. The network-related technical basis for the telegram is the subdivision of the network areas into bottleneck zones, which will also be filed and visualised in the control system. If a well-defined alarm value has been exceeded, the operators will get an immediate overview of the critical area. In the bottleneck areas, the feeding units are grouped according to the legal stipulations (RPP have priority over other types of power plants). If an inadmissible state is detected by the evaluation tool in the control system, the system will calculate and also display the amount by which the feeding capacity has to be lowered. First, all those power plants which do not fall under the EEG have to be reduced in the bottleneck zone, all other remaining feeding units will be called to lower their capacities until the bottleneck capacity is undercut. According to the procedure applied, this is effected either in single steps (e.g. to 60 %, 30 % or also 0 % of the installed capacity) or depending on the order of the commissioning of the RPP (first in, last out). No legal stipulations on this have been made so far. The selection template provided in the control system is illustrated in Fig. 6.

Each process step is documented both by the system and the operating staff so that it is always possible to prove the correct capacity reduction also for later purposes. The exact amount of the capacity reduction of the individual RPP can be checked on the basis of the count values. Up to now, the NSM has had to be strategically used in both companies in only few cases. However, experiences show that the technical solution proposed is able to meet the expectations and that the system can easily be handled by the operating staff.

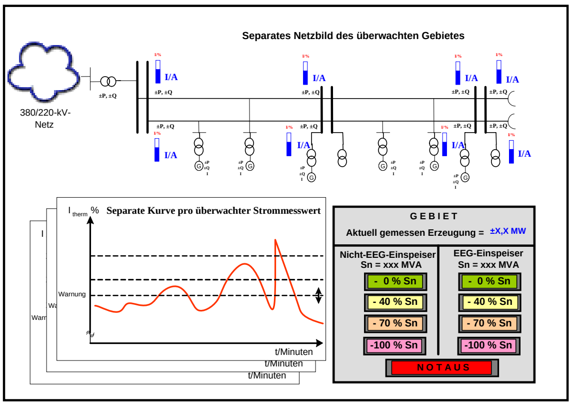

Fig. 6: screen of the network control system

On the other hand, the statements made by the network operators on the frequency and duration of NSM uses are very important for the runners of wind farms as these statements allow experts to assess the profitability of the RPP in the investment phase. These influencing variables being highly stochastic, the statements made can only be of a statistical character. In paper [4], the results obtained in such investigations are presented.

APPLICATION OF THE NSM TECHNIQUE FOR GUARANTEEING SYSTEM SECURITY

Also the transmission network operators place new requirements on the RPP. For example, wind turbines with an installed capacity of about 7,300 MW are connected at present in the network region of the transmission network operator Vattenfall Transmission (VET). This capacity corresponds approximately to 39 % of the overall installed capacity of wind turbines throughout Germany. However, the end user consumption amounts only to about 18 % of the overall consumption in Germany. In situations of considerable wind energy feeding and low loads, it will become increasingly difficult, if not possible, to maintain the system balance only by applying conventional control measures (negative minute reserve capacity, running down the base-load stations to minimum load). Also in such cases, particularly the wind power stations as cause of the problem must be controlled down. Thus, from the point of view of the transmission network operators too, a capacity control of those power plants whose feeding is not tailored to suit the needs of the market becomes necessary.

As the transmission network operators have direct access only to the power plant s in their own networks, but not to those in the distribution networks, the distribution network operators will be obliged – whenever the situation arises - to carry out the necessary capacity reductions when they are requested to do so.

As practically the same loop as in the case of the NSM must be utilized, the idea suggests itself to lay out the management system in such a way that the requirements placed by the transmission network operators can be fulfilled. In contrast to the NSM applied in the interest of the distribution network operator, the impetus is given this time by the control centre of the transmission network operator. It has already become necessary to apply the NSM also in this way. On 31st December 2006, both network operators had to reduce their feeding capacity of about 600 MW for several hours in order to maintain the system balance in the control zone of the VET company. Also in this case, the NSM system proved to be successful.

OUTLOOK

The biggest challenge for the network operators is to integrate the renewable power plants into the already existing supply network and to feed the energies generated. Even at present, considerable network extensions are necessary, with further bottlenecks having to be expected in the future particularly due to off-shore wind farms. Therefore, the politicians are called upon to create the basic conditions for a better network integration. From an economic point of view, it is questionable whether the networks shall be upgraded for situations which will most probably occur very seldom only during the year, with this aim being pursued at present in Germany, particularly as the new erection of lines becomes more and more difficult due to the lengthy approval procedures. Thus, only the feeding according to the needs of the market and/or the promotion and application of appropriate storage technologies can be regarded as real alternatives. The newly built renewable power plants have to fulfil more and more also tasks of conventional power stations (such as network support in the case of malfunction, voltage/reactive power control).
Furthermore, the requirements to be met by the strategic network control are also increasing. While the NSM can still be carried out manually by the operating staff at present, it will be possible to handle this system in the distribution networks in the future only by means of a highly efficient software.

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