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Increasing Dispersed Power Generation Leads to "Network Safety Management Systems" (NSM) in Germany

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Abstract: - The rapid growth of the renewable energies causes difficult load situations in the power supply system in Germany. The legislator prescribes that the network operators have to connect all dispersed generation. Especially the distribution networks become more and more overloaded during strong wind situations combined with low network load. Since some month the network operators now legally have the right to disconnect critical feeding from the grid in case of critical overload. The first two utilities in eastern Germany started their "network safety management system" right now. The following paper will describe the situation in these grids and how the NSM-System will work.

Key-Words: - Network Safety Management System, Renewable Energy, Distribution System Operator

1 Introduction

Due to a very high governmental funding of renewable energies in Germany during the last decade, the amount of installed dispersed generation, especially wind power increased tremendously. In strong wind situations medium voltage and 110 kV distribution networks are close to or above their transport capacity. Transmission network operators are more and more faced with critical situations to balance generation and load in the grid.

1.1 Renewable energies in Germany

Generation from renewable energies was recognized in Germany since mid of 1970. In the time period from 1975 to 1995 approx. 3000 MW was installed in total, especially in wind power. At that time the German government decided to establish a national law (1) to promote renewable energies (EEG). While the normal generation costs from thermal power plants are in the range of 3 Euro Cent /kWh a rate of 8.7 Euro Cent / kWh from wind energy is guaranteed. Biomass generation will be granted with up to 11.5 Euro Cent /kWh and for energy from photo voltaic up to 57,4 Euro Cent per kWh will be paid.

That will lead to a rapid increase of wind power in Germany. Since that up to 3000 MW per year will be brought to the grid. In 2005 an installed capacity from renewable energies of total 24.000 MW is on the grid.

In the Table 1 the allocation from renewable energy is shown. The wind energy has the greatest contingent.

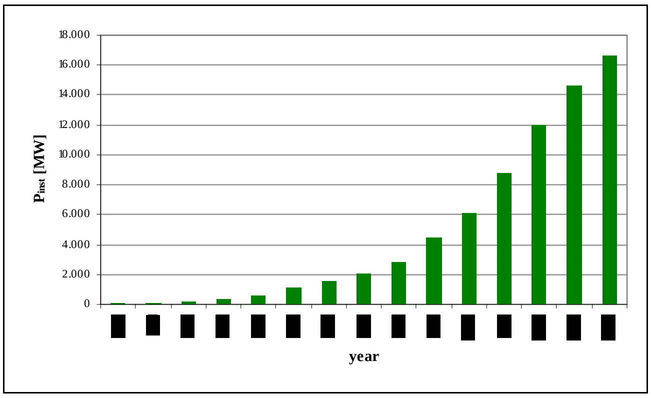

Figure 1: Installed load of wind power plants in Germany [2]

In the last years more and more a situation is reached where parts of distribution networks will be overloaded assuming full wind power feeding combined with low load in the grid.

	installation power		produced energy	
	P_{inst} [MW]	Ratio [%]	W [GWh]	Ratio (sum of genera-tion) [%]
sum of generation	114.600		570.100	
renewable energy plants				
wind power	16.629	14,5	25.000	4,4
water power	4.660	4,1	21.000	3,7
biomass energy	2.061	1,8	9.367	1,6
photovoltaics	708	0,6	459	0,1
sum (renewable)	24.058	21.0	55.826	9,8

Table 1: Overview from installed load and electric work in Germany [2] [3]

An example is shown in the 110 kV network of eon-edis, utility which supplies the area around the city of Berlin and the region north towards to the Baltic Sea. Network districts which are overloaded in case of strong wind situation are marked in red colour. Overloaded 110 kV lines are marked with fat and black.

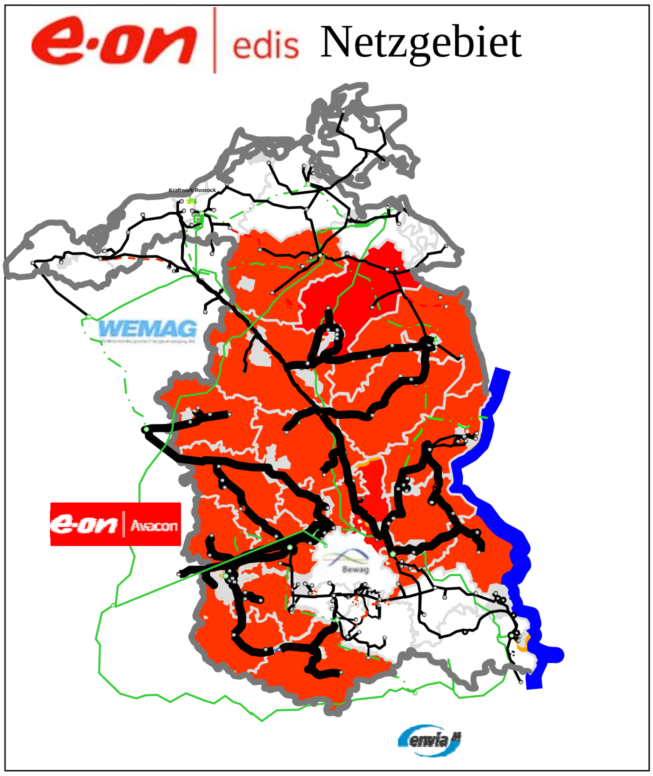

Figure 2: Net of eon-edis including NSM affected areas (marked in red colour)

That leads to a national discussion to expand the medium and high voltage overhead lines in Germany. In 2004 a network study from the German National Energy Agency (DENA) was carried how to forecast the possible amount of wind energy in Germany up to the year 2015 and to investigate how to integrate these generations to the grid. Up to another 20.000 MW of wind energy is forecasted in this time period, mainly off-shore in the German North Sea.

Up to the year 2010 in total 6 new 380 kV transmission lines with a length of 450 km have to commissioned. 6.600 Mvar of additional reactive compensation will be necessary. Up to 2015 another 400 km of 380 kV transmission lines have to be connected to the grid, additional to hundreds or thousands km of 110 kV or medium voltage lines.

Figure 3: German high voltage grid with marked area of Vattenfall Europe Transmission

Due to past experiences, it can take 5 to 10 years to get all necessary permissions to build a new line in Germany. German government start to improve the boundary conditions to speed up network work expansion, but meanwhile network safety management systems will be established to keep the grids stable.

1.1.1 Renewable energies in the Federal State Brandenburg

Brandenburg is a federal state in Germany surrounding the city of Berlin. It has a low population density (86 inhabitants /km^2; Germany: 222 inhabitants /km^2). Therefore this region is a preferred location to install renewable energy plants.

	installed power		electric energy	
	P_{inst} [MW]	Ratio [%]	W [GWh]	Ratio (generation) [%]
Renewable generation	2.515		4.601	
wind energy	2.300	91,5	3.082	67,0
biomass energy	200	8,0	1.481	32,2
photovoltaics	10	0,4	8	0,2
water energy	5	0,2	30	0,7

Table 2: Installed power and produced electric energy from renewables in Brandenburg

With a share of 90 %, wind energy is absolutely dominating in Brandenburg (see Figure 4). In the first half of 2005 the installed capacity increases by another 128 MW.

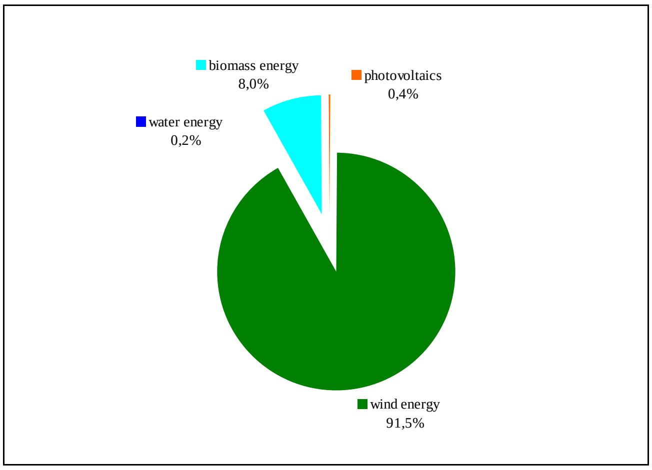

Figure 4: Allocation of renewable installed generation in Brandenburg [4]

In the state of Brandenburg a potential for wind energy of 1.600 MW was detected, additional to 350 MW from repowering and some hundreds MW from biomass and photo voltaic.

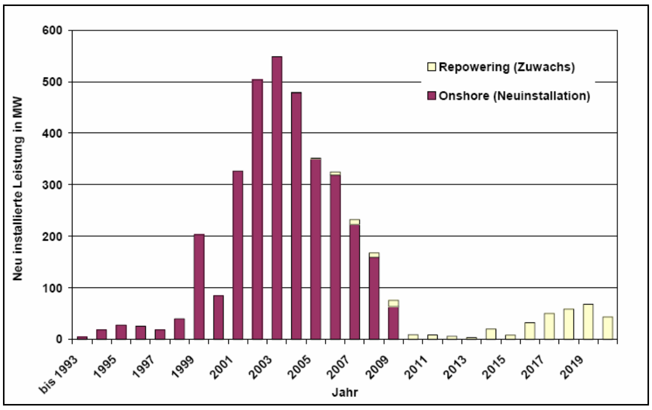

Figure 5: Expected increase of installed load in Brandenburg

2 Structure and actual situation of the transmission and distribution networks in Brandenburg.

The 380 kV and 220 kV transmission network in Brandenburg as well as in the rest of East Germany will be operated by Vattenfall Europe Transmission.

Figure 6: Net of Vattenfall Europe with distribution system operators in Brandenburg (dark colors)

Critical situation in the transmission grid not only can occur when load and generation is unbalanced. In case of 3 phase short circuit at critical locations up to 3.000 MW of wind power generation will be lost due to undervoltage in the grid.

Figure 7: Part of german net in case of 3 phase short circuit in Wolmirstedt [5]

Three different 110 kV distribution networks in Brandenburg are operated by:

- E.ON edis AG (edis)
- envia Verteilnetz GmbH (envia)
- WEMAG

About 70 % of the wind energy in Brandenburg will be fed into the edis grid, another 20 % to the envia net.

2.1 Situation in distribution networks

In transmission networks normally critical situations may occur when the net is strongly loaded due to high energy demand or transits and a strong wind situation will rise up. Main problems are to keep the frequency or voltage stable, while large amount of fluctuating energy will be fed into the grid.
The main critical operation situation in a distribution network will occur when a strong wind situation will be combined with low energy demand in the net. The distribution lines have to transport the unneeded energy to the next interconnection transformer to the overlaid transmission grid. Main problem will be the thermal capacity of the overhead lines and assets.

2.2 (n-1) Security

With respect to the German law network operators have to ensure a save supply with electrical energy. That will include that the system has to be stable, while one line will be lost by short circuit or other failures (n-1 security). Furthermore it should be possible to maintain one line, to have a failure on another line and to keep the system still stable. These operation rules have to be taken into consideration also when discussing possible overload situation during strong wind and low load situations.

Therefore envia and edis take their permanent on-line (n-1) load flow calculations as a basis for their Network Safety Management System. An occurring overload situation will lead to the disconnection of power infeeds.

2.3 Actual Situation within envia and edis network

End of 2005 envia has to handle 2.000 MW infeed from dispersed generation, 1.800 MW from wind energy. Peak load is 3.500 MW and low load reaches 1.300 MW. The percentage of energy produced by wind generation will be 15 % (German average 4,4%). Much more critical is the situation in the edis network. While total renewable generation is 2.400 MW (2.200 MW from wind), the peak load will only reach 2.300 MW and the low load is 800 MW. Percentage of renewable energy is 31 %.

In the following both tables below an overview will be given, how many lines will be affected by the NSM in the year 2005 and 2015. The category “close before” should represent that this number of lines are not in the NSM at that moment, but it will be expected to include them to the NSM within the following year.

	Percent of wires (110 kV) are affected by NSM		
year	**no**	**close before**	**yes**
2005	69	15	16
2015	39	4	57

Table 3: Percentage of lines affected by “Network Safety Management System” in Brandenburg part of envia net

Restrictions for infeeding of renewable energies will occur in up to 95 % of these both distribution networks within the next years.

	Percent of wires (110 kV) are affected by NSM		
year	**no**	**close before**	**yes**
2005	22	15	63
2015	0	5	95

Table 4: Percentage of lines affected by “ Network Safety Management System” in the Brandenburg part of edis net

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3 How the NSM acts

To realize a simple operability, edis and envia structured their networks into several sub-systems, each of them connected to the 220kV or 380 kV transformers. For each sub-system the maximum current for lines or assets is defined.

Since mid of this year each feeding, which will be connected newly to the net has to install a control unit. These control units allows the system operator to influence the amount of feeding (renewable or conventional).
In case of occurring critical load situations envia and edis developed different procedures how to influence the different types of feeding.

3.1 envia Verteilnetz GmbH (envia)

Envia follows the idea “last in, first out”. Therefore envia splits the year into several periods, in which a comparable amount of newly installed generation will be connected to the different network sub-systems.

If an overload of a line seems to be possible the operator activates the disconnection of the last connected set of generation in respective sub-system. If the situation will still stay critical the next set will be disconnected. No difference will be made on the type of generation (wind, bio mass, photovoltaic) or height of installed capacity (MW or kW).

This type of systematic will ensure the economical basis of renewable generation for those who connected their generations to grid in a time with enough transport capacity of the lines.
Those one who will be connected in a time of restricted transport line capacity will have a higher risk of partial disconnection and therefore a higher economical risk for their investments.

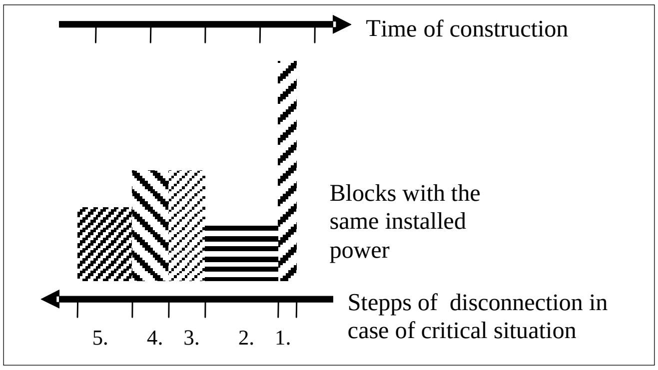

Figure 8: Principle of Network Safety Management System in the network of envia

3.2 E.ON edis AG (edis)

Edis focus on the installed generation capacity, which is contractual defined which each “renewable customer” at the connection point. These capacities will be structured into four different groups.

Feeding connected to the grid before establishing NSM will be only influenced in case of an emergency switch off. Connected feedings after establishing NSM will be clustered into large (< 5MW), medium (5…0,5 MW) and small (>0,5 MW) infeeds.

In case of overload large infeeds have to reduce their capacity down to 60 % of the rated value.

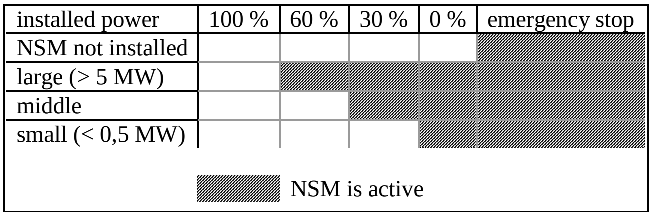

Figure 9: Principle of Network Safety Management System in the network of edis

If this reduction will not clarify the overload situation, in the next step all feeding above 0,5 MW have to reduce down to 30 %. The last step is to reduce all feeding down to zero. The power producers will have an agreed response time for their reductions. An emergency switch off will act directly and without delay to all producers.

Within one group of generation this procedure will make no difference, at which time the power producers connected their generations to the grid. Therefore each feeding in a specific network sub-system will be affected in the same manner by the NSM. That will increase the economical risk for “early” investments, but will promote small generation, e.g. from bio mass.

4 Conclusion

Due to intensive funding of renewable energies by the German government, the amount of dispersed generation (especially wind generation) increased rapidly within the last decade.

Roughly 16.000 MW of wind power was installed in Germany mid 2005 and a potential of another 20.000 MW will be expected.

The upcoming critical situations in the German transmission and distribution grids during strong wind periods will lead to "Network Safety Management Systems" established by the first German Distribution utilities.

Emergency plans to reduce grid feeding by renewable energies follow different guiding ideas. Two of them, both from East German distribution utilities are presented in the paper.

One strategy is guided by the idea "last in – first out" and will ensure the economical basis of renewable generation for those who connected their generations to grid in a time where transport capacity of the lines were high enough.

Those one who will be connected in a time of restricted transport line capacity will have a higher risk of partial disconnection and therefore a higher economical risk for their investment.

The other strategy will focus on the installed generation capacity which is contractual defined which each "renewable customer" at the connection point.

These capacities will be structured into four different groups, according to the height of generation and will be influenced in several steps from 100 % feeding down to zero.

Because each feeding in a specific network sub-system will be affected in the same manner, that type of NSM will increase the economical risk for "early" investments, but will promote small generation, e.g. from bio mass.

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