INTEGRATION OF DISPERSED WIND GENERATION TO THE EAST GERMAN NETWORK

Milthon SERNA SILVA
CCET/NEL UFS – Brazil
milthons@yahoo.es

Harald SCHWARZ
BTU Cottbus – Germany
harald.schwarz@tu-cottbus.de

Klaus PFEIFFER
BTU Cottbus – Germany
klaus.pfeiffer@tu-cottbus.de

ABSTRACT

According to the EU guidelines, renewable energies should account for a minimum of 21 percent of European power generation by 2010. Wind energy occupies special importance in German energy planning: By 2020, wind parks on land and at sea should theoretically supply 20 percent of the power consumed in Germany but this rapid growth is causing difficult load situations, especially when the distribution network becomes overloaded during strong wind situations combined with low network load.

This paper evaluates the Network Safety Management Systems (NSM) into the future, using simulating scenarios.

1. INTRODUCTION

In the last fifteen years, the interest in the use of renewable energy sources for electric power generation has increased considerably. Among the reasons for that interest, can be highlighted the need to search for alternatives to substitute the use of fossil fuels due to their high cost and the necessity to reduce the emission of pollutant gases stated by the Kyoto Protocol signed in 1997 in Japan.

Wind energy is the renewable energy source with the most successful exploration currently. A reason for this fact is the incentives politics promoted by several countries, ensuring the purchase of the wind energy produced in spite of its uncompetitive prices. Germany and Denmark were pioneers in this procedure, followed by other countries. In the case of Germany due to very high governmental funding during the last decade, the amount of installed dispersed generation, especially wind power, increased tremendously.

The German wind energy installations can expand from almost 17 GW today to 36 GW in 2015 and 48 GW in 2020 and the Wind energy annual production can triple from 23,5 TWh in 2003 to 77,2 TWh in 2015, providing 14% of the German net electricity consumption in 2015 [5].

A gradual increase in effective wind turbine capacity has been calculated corresponding with expected wind energy technology improvements and the use of more windy locations, in promoting the reduction of the cost of wind generation.

However, wind generation has disadvantages as a regular energy source and is considered less reliable than conventional sources. The amount of energy available daily can vary a lot from one season to another at the same site, and its use is limited to sites of strong and relatively constant winds.

Taking as an example the information of a utility in Germany, the installed wind capacity is 7,15 GW and the maximum daily wind fluctuation is 5,29 GW, this fluctuation of more than 5 GW will cause severe problems in keeping the system stable.

Companies that need to evaluate the implementation of this type of generation are very concerned with the intermittence of the wind and with the uncertainties introduced in the planning and operation of their electric systems.

It is well known that power generation from wind and also from photovoltaic cannot yet be forecast in a proper way. Therefore the successful use of these types of renewables for electricity supply is directly related to the compatible adoption of the fluctuating infeed to the physically based rules on how to operate electrical grids.

2. EAST GERMAN WIND GENERATION

Generation from renewable energies was recognized in Germany since the mid 1970s. In the time period from 1975 to 1995 approximately 2700 MW were installed in total, especially in wind power. At that time the German government decided to establish a national law [4] 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 9 Euro Cent/kWh from wind energy is guaranteed.

At the end of 2005 were installed approximately 24.000 MW of renewable energies on the grid. In the Table 1 the allocation from renewable energy is shown. The wind energy has the greatest contingent.

Table 1. Overview from installed load in Germany [1,7]

	Installation power		Produced energy	
	P_{inst} [MW]	Ratio [%]	W [GWh]	Ratio [%]
Total 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
Photovoltaic	708	0,6	459	0,1
Total renewable	**24.058**	**21.0**	**55.826**	**9,8**

In the last years a more and more critical situation has been reached where parts of the distribution networks will be overloaded assuming full wind power feeding combined with low load in the grid. That leads to a national discussion to expand the high voltage overhead lines in Germany. From past experiences, it can take approximately 10 years to get all the necessary permissions and build a new line in Germany.

German utilities started to improve the boundary conditions to speed up network expansion, but meanwhile network safety management systems will be established to keep the grids stable.

In 2004 a network study from the German National Energy Agency (DENA) was carried out 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 [2]. Up to another 20.000 MW of wind energy is forecasted in this time period, mainly off-shore in the German North Sea.

Figure 1 shows the rapid increase of wind power generation in Germany.

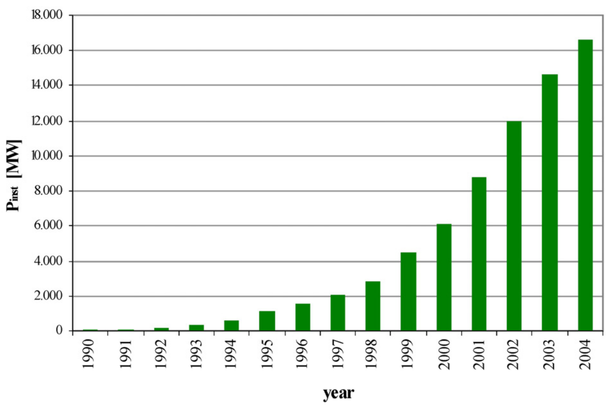

Figure 1 –Increment of installed wind power in Germany [1].

3. WIND POWER GENERATION PROBLEMS

In total 59 GW of generation from wind power is installed around the world. With a capacity of nearly 18 GW (end of 2005) about 31% of the world wide wind capacity is connected to the German grid.

This situation in the last years is generating the lines transmission overloading that happens in periods of time with full wind power feeding combined with low load in the grid.

It is well known that power generation from wind and also from photovoltaic cannot yet be forecasted in a proper way. Therefore the successful use of these types of renewable electricity supplies are directly related to the compatible adoption of the fluctuating infeed to the physically based rules on how to operate electrical grids.

The European supply system for electrical energy is designed as a continental 400 kV system, which will be operated by several TSO's (Transmission System Operator). These have the responsibility for the safe and reliable operation (frequency, voltage) of their part of the European grid. In consequence of an intensive use of wind generation it is one of their main duties to compensate the intra day fluctuations of infeeds, this compensation energy has to be bought or sold on the spot market normally at a very high price level. The Figure 2 shows an example between the day ahead forecast and the real infeed over a 24 hour period.

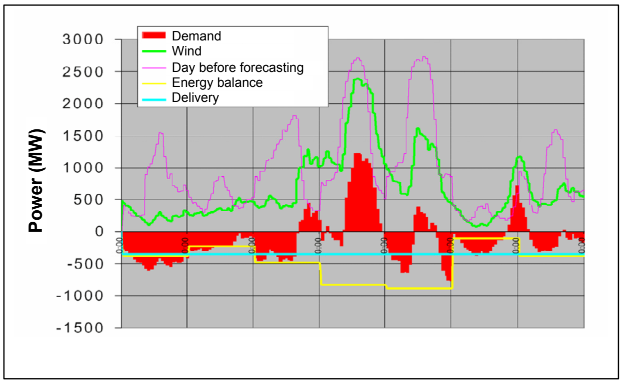

Figure 2 – One day real wind power generation forecasting [6]

These reflections of an intensive use of wind power generation lead to a restructuring of the grid structure itself. But this is a very time consuming procedure. In the actual revision of the EnWG (German Law on Energy Economics), the national government gave the opportunity to the utilities to adjust all relevant infeeds, transfers and loads in case of occurring system stability risks. To organize this on a technical basis, all generations (renewable or non-renewable), which want to be connected newly to the grid now are forced by law to install a device for remote control.

Although the system stability might be guaranteed within the grid, lines, cables or other equipment can be overloaded during a strong wind and low load situation in specific areas of the grid. To avoid disconnection of lines due to thermal overload, dispersed generation might be disconnected within several periods of time. NSM's (Network Safety Management Systems) were commissioned in the East German Grid in the last months and had to be activated several times [5].

On the hand in electrical grids severe voltage drops will occur after short circuits. In case the voltage drops below 85 % of rated voltage, older types of wind power generators will be switched off. The investigation of the 380 kV national German grid showed that in case of a 3-phase short circuit at relevant nods in the grid a wide spread voltage drop will occur combined with an immediate loss of up to 4 GW of wind power [2].

Another problem with relation to using wind energy is the generation of reactive power, because this type of generation is not able to deliver reactive power to the grid and the frequency itself is a large consumer of it. In the case of a strong wind situation the problem frequently occurs that directly coupled generators in conventional power plants must be disconnected from the grid to keep the system stable. But this will also lead to a lack of reactive power which will be needed for the operation. This again will cause problems with the voltage stability in the systems.

4. THE NSM PERFORMANCE

With respect to the German law network operators have to ensure a safe supply of electrical energy. That includes that the system has to be stable, when one line is 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 stable. These operation rules have to be taken in consideration when discussing possible overload situation during strong wind and low load situations.

Therefore the East German utilities 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. Since the middle of this year each feeding, which will be connected newly to the net has to install a control unit. These control units allow the system operator to influence the amount of feeding (renewable or conventional). In case of occurring critical load situations the utilities developed different procedures on how to influence the different types of feeding.

One utility follows the idea that the date of erection is the criteria for the chronological order of disconnection of generating units in case of overload. Units first erected and connected to the grid take priority over units with a later date of erection.

Other utility 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 only be influenced in case of an emergency switch off. Connected feedings after establishing NSM will be clustered into several priority classes: priority I with installed capacity > 5MW, priority II with installed capacity in the range of (5…0,5) MW and priority III with a capacity of ≤ 0,5 MW. Infeeds with a capacity ≤ 0,03 MW are excluded from the NSM. In case of overload and call for reduction step 1 feeder with priority I have to reduce their power down to 60 % of the rated value as shown in figure 3.

Priority		Participation for call of				
		Step 0 100%	Step 1 60%	Step 2 30%	Step 3 0%	ES
0	NSM not installed					
I	> 5 MW					
II	< 0,5 MW … ≤ 5 MW					
III	≤ 0,5 MW					

Figure 3 – Principle of NSM System

ES Emergency Stop
NSM is active

If this reduction does not clarify the overload situation, in the next step feeder belonging to priority classes I and II have to reduce down to 30 %. Step 3 is to reduce all feeding (priority I to III) 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.

5. WIND ENERGY SIMULATED SCENARIOS

To carry out the simulation and comparison study of different scenarios with and without expansion of the net, the following steps were carried out: First a net model was chosen in which different substations are installed with wind park (WP) and conventional electric (CS) generation units that are interconnected inside of a ring topology (as shown in the figure 4).

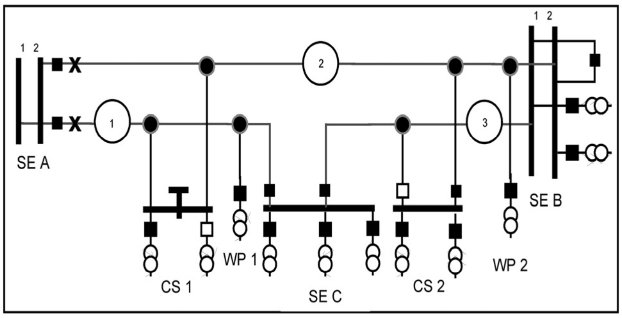

Figure 4 –The model of transmission net chosen.

For this net model a database was created with all electrical parameters information of each existent substation (voltage, active power, reactive power, etc.), considering their evolution during 2004. Within this database specific days were chosen that represent each one of the seasons (summer, winter, etc), taking into consideration the information of a working day during the week and another day at the week end. All the data were collected using a 15 minutes sampling rate.

Using the data of the chosen days the dynamic load flow was calculated for each one of the mentioned cases, whose values are shown in the table 2.

Table 2. Calculated dynamic load flow of the 2004 database

Lines / Days	U [KV]	I [A]	P [MW]	Q [MVAr]
SEA - SEB				
03/01/04	115.5	0.0	0.0	0.0
07/04/04	114.1	0.0	0.0	0.0
05/07/04	114.6	26.6	5.3	0.2
SEA - SEC				
03/01/04	115.2	83.9	14.3	2.2
07/04/04	115.1	74.9	11.9	3.6
05/07/04	115.2	85.6	14.3	2.4
SEB - SEC				
03/01/04	115.2	56.8	8.5	6.3
07/04/04	115.1	44.9	5.4	6.2
05/07/04	115.2	58.6	9.9	5.3

Following this model, other databases information for 2005 and 2006 was entered, which allowed comparison and estimation of the increment grade (percentage). This percentage was taken as representative for the future scenarios forecast with a possible net expansion. With the data of these years the dynamic load flow was calculated using the same methodology applied for 2004.

At the moment new future scenarios are being simulated considering nets with new wind generator units until 2020, which information is being analyzed now.

6. CONCLUSION

The increasing use of wind generation request modifications in the electric system analysis, because it includes uncertain components, needs to be studied properly and modeled. It was verified that the contribution that the wind farms can supply to an electrical system depends strongly on the combination of the used turbines and the behavior of the local wind.

Acknowledgments

The authors wish to thank Dr. Wolfgang Gallas of envia Verteilnetz GmbH and Paul-Dieter Gorgas of E.ON edis AG, for their contributions and participation in the project execution.

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