Requirements for integration of wind energy into the grids of various countries

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Introduction

In Europe and around the world, wind energy is developing at an incredible growth rate. Countries such as Denmark, Germany and Spain have created a major foundation for integrating wind energy with their pioneering work. In 2030, wind energy is to provide more than 25% of the electricity requirement in Europe [1].

This high percentage of wind energy generation presents an enormous challenge for reliable and safe integration of wind energy in supply grids. As a consequence, the need to manage wind farms like conventional power plants in terms of predictability and grid compatibility is increasing in order to guarantee a reliable and safe integration of wind energy. The country-specific regulations and requirements for the energy market and electricity grids are framework conditions which must be taken into account when developing system technology and the tools for planning, monitoring and management.

The term "power plant properties for wind farms" indicates that wind energy generation must be controllable and reliable in accordance with the system requirements, and that wind turbines must support the electric grid in the event of disturbances. These capabilities are based on management of active and reactive power of the wind farms and their reactions in the event of grid disturbances such as fault ride through [2] capability, an ability with which wind turbines can survive temporary voltage drops and thus contribute to grid stability.

Grid integration status

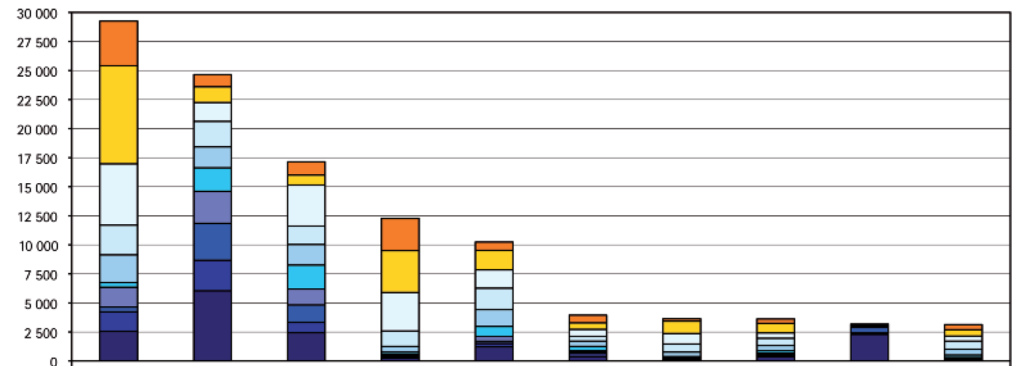
One of the largest barriers to further development of wind energy technology is the restricted capacity of the transmission grids. Large-scale balancing of wind energy feeding by transporting energy long distances decreases major fluctuations to a great extent [3]. This requires an efficient and sustainable expansion and strengthening of the European transmission grid and, in particular, of the connection points, in conjunction with detailed planning and early detection of grid bottlenecks at a European level.

Future reliable and economic grid planning and safe grid operation also require reliable monitoring, better understanding and precise predictability of the respective grid status. This results in the need for improved monitoring, simulation and prediction tools, in conjunction with dynamic analysis and evaluation of the joint European system.

The development status of wind energy use in Europe is very different in the individual countries. For example, the installed capacity in Germany and Spain is at a double-figure gigawatt level, followed by Italy, France, Great Britain, Denmark and Portugal.

Worldwide, currently approx. 130,000 MW of wind capacity are installed, and the growth rate is immense. In some countries, wind power generation at times covers more than half of the entire load (Denmark, Spain). The challenges for an electric energy supply system with a very high proportion of wind energy are

- The variability of wind energy feeds,
- Forecast errors for wind feeds,
- The electric grid for absorbing and transporting wind energy.



	USA	Germany	Spain	China	India	Italy	France	UK	Danmark	Portugal
Installed in 2009	3 837	1 047	1 140	2 776	720	660	211	383	- 2	434
Installed in 2008	8 437	1 353	855	3 594	1 678	564	1 057	817	47	550
Installed in 2007	5 273	1 625	3 530	3 312	1 574	603	901	467	- 12	434
Installed in 2006	2 556	2 195	1 587	1 334	1 836	406	699	616	9	692
Installed in 2005	2 390	1 799	1 765	496	1 451	452	380	445	9	501
Installed in 2004	400	2 019	2 061	198	863	374	150	193	42	224
Installed in 2003	1 707	2 759	1 372	98	418	106	93	152	187	105
Installed in 2002	400	3 179	1 495	69	195	88	62	67	472	67
Installed in 2001	1 690	2 633	904	59	287	308	6	76	120	27
Actual decembre 2000	2 555	6 038	2 431	340	1 220	389	79	409	2 297	100
Actual july 2000	**29 245**	**26 647**	**17 140**	**12 276**	**10 242**	**3 950**	**3 638**	**3 625**	**3 169**	**3 134**

Table 1
Wind capacity installed worldwide.
Diagram: Fraunhofer IWES

The grid integration status quo in these countries is such that the grid can largely absorb and transport the energy from the turbines which exist today. However, the grids in some countries are rapidly approaching their capacity limits. When comparing the requirements for grid integration in various countries, it is not sufficient to use the installed wind capacity as a measurement variable. The impact of wind power feeding on grid operation also depends on the following factors:

- The percentage of wind power in the grid (% min, % avg, % max)
- The variability of the load
- The flexibility of the conventional power plant infrastructure
- Ways of increasing the flexibility of generation and load
- The structure of the grid (wind locations – load centres)

The degree of penetration can be measured by the energy or powerWind energy penetration in European countries.

In the IEA Wind Annex 25 [4], the penetration was also measured based on the minimum load and the grid capacity. This representation shows

	Load			Inter-connection	Wind capacity 2007	Maximum investigated		Maximum penetration		
Region/ case study	Peak MW	Min MW	TWh/a	MW	MW	MW	TWh/a	%	%	%
								Peak load	Con-sumtion	(Min load+ interconn)
West Denmark real	3700	1300	21	2830	2380		5,00	65%	24%	58%
Denmark 2025	7200	2600	38	5190/6790	3125	6500	20,20	90%	53%	83%/69%
Irleand 2020	9600	3500	54	1000	900	6000	19,00	63%	35%	178%
Portugal	8800	4560	49,2	1000	2150	5100	12,80	58%	26%	92%
UK	76000	24	427	2000	2389	38000	115,00	50%	27%	146%
Germany 2015	77955	41000	552,3	10000	22247	36000	77,20	46%	14%	71%
Spain 2011	53400	21500	246,2	2400	15145	17500		33%	19%	73%
Sweden	26000	13000	140	9730	788	8000	20,00	31%	14%	35%

Table 2
Wind energy penetration in European countries

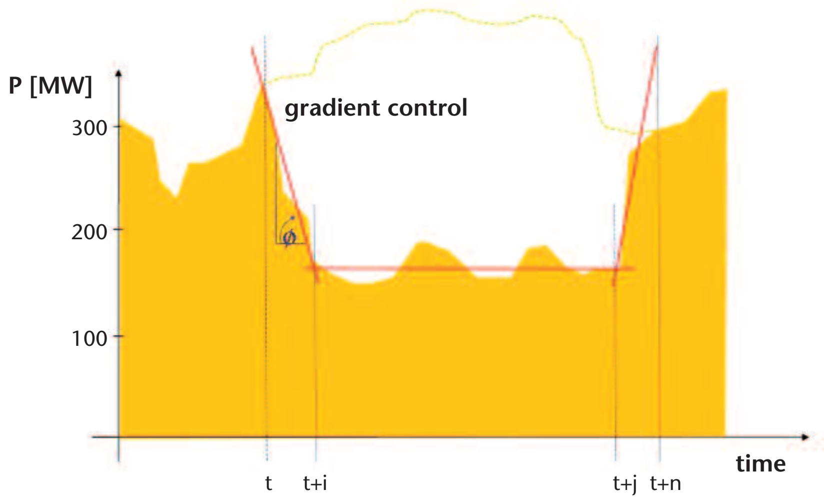


Figure 1
Active power control – gradient control with WCMS.
Diagram: Fraunhofer IWES

the challenges at high wind feed rates in low load periods. It also illustrates the special features of stand-alone systems compared with well-connected areas.

Table 2 shows the current and expected penetration of wind energy in some countries in Europe. For example, in Germany it is expected to reach 14% of peak load and 71% of the minimal load by 2015. With this high penetration rate, wind capacity will soon significantly exceed the load in many countries. The wind power generated must therefore be transported long distances to facilitate an exchange. One of the main tasks for research and the industry is to develop future grid planning tools for designing a sustainable, powerful European grid infrastructure. In particular, the new international offshore connections and an offshore supergrid must be designed.

Future challenges

Grouping multiple large-scale offshore wind farms and other distributed wind turbine groups to wind farm clusters [5] opens up new ways of optimally integrating yield-dependent generation into electric supply systems. The Wind farm Cluster Management System (WCMS) developed by Fraunhofer IWES is responsible for grouping the geographically distributed wind farms for optimal grid operation management and minimisation of the reserve and balancing capacity requirement, and mapping and managing it as a single large-scale power plant feeding into multiple extra-high voltage nodes. With the aid of new operating management concepts for active and reactive power control, higher levels of wind power can be integrated in supply systems.

As a result of the system topology, the following system levels must be considered:

- Individual wind turbine
- Individual wind farm
- Geographical, grid-topology and control-technical grouping of multiple wind farms to a wind farm cluster

For modern wind farms and with corresponding wind farm controllers, the following control and operation management strategies are currently state-of-the-art or achievable:

- Feeding reactive power based on setpoint specifications
- Maximum value restriction based on setpoint specifications
- Compliance with maximum gradients based on setpoint specifications
- Power restriction in the event of excess frequency

The following advanced strategies can also be implemented using the options above:

- Scheduled specifications (time-variable specification of maximum values)
- Voltage control in high/extra-high voltage grids
- Rapid voltage control in medium-voltage grids
- Provision of balancing capacity

Based on these options, future control and operation management strategies can be derived for wind farms:

- Reactive power feed
- Generation management
- Scheduled specifications
- Voltage control at high and extra-high voltage levels
- Provision of balancing capacity
- Primary control capacity

Literature

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