Cost Efficient Large Scale Onshore Wind Integration

Guenther F.W. Brauner
Institute for Energy Systems
Technische Universität Wien
Wien, Austria
guenther.brauner@tuwien.ac.at

***Abstract*—Renewable energy especially from wind and PV will in future replace fossil energy. The grid integration of these sources with high generating power at low time of usage forms a challenge to the existing grid. New design of wind generators for low wind application will help to reduce the installed wind power and the grid investments.**

Keywords: wind integration, onshore, cost efficient

I. INTRODUCTION

The energy turnaround will result in photovoltaic and wind energy as the dominant generating technologies [1], [3], [6]. Photovoltaic itself will be mainly installed on buildings and in future be equipped with battery storage capacities [2]. A balancing of the installed PV by battery capacities according to the local demand can result in full usage of the solar energy in decentralized concepts. Photovoltaic will then need nearly no grid extension in the distribution and transmission level. PV is then a renewable generating technology to reduce the load but no more a centralized generating concept.

Wind energy has in future the tendency to big power installations. Wind generators will exceed the 10 MW margin [1], [6]. As large wind farms are in areas of high wind potential, which may not be bulk consumer areas they need extensions especially in the transmission grid level. Today the European transmission grid has reached it load ability limits. Congestion management in the European transmission grid especially due to wind energy has become prominent [5]. Due to grid overloading in the northern region wind parks had to be partially shut down and in the southern region thermal power plants had to be started to stabilize the transmission grid. The payment for these measures has reached meanwhile (2015) 200 Mio Euro per year.

The adequate grid extension forms the main barrier for the further development of wind energy. In history the security margin of the grid could be given at no charge for the integration of wind energy. Meanwhile this capacity margin is exhausted and grid extension must be performed in parallel to wind integration to avoid system instabilities.

In this paper the following questions are discussed:

- Has the grid to be adapted according to the installed wind generation in traditional converter design?
- Should the wind generators be adapted by a new designed for lower need of grid extension, this means in direction of power reduction and energy harvesting enhancement at higher usage time?

In the following it will be shown, that low wind design reduces grid extension costs.

II. NUCLEAR DECOMISSIONING AND WIND DEVELOPMENT IN GERMANY

Germany will fade out from nuclear energy until the year 2022 [4]. The decommissioning of nuclear and fossil energy will be substituted by renewable energy. For a rough estimation Germany can be subdivided into three areas: north, middle and south (Table I).

TABLE I. DECOMISSIONING OF NUCLEAR AND NEW WIND

Area	decomm. of nuclear	Potential nuc.annual energy	Wind power 30.06.2016	Wind energy 2016*
	GW	TWh/a	GW	TWh/a
north	11.1	89	18.4	32
middle	4.5	36	19.0	24
south	11.7	93	6.2	7
sum	27.3	218	43.6	63

*) estimation

In total 27.3 GW of nuclear power plants will be decommissioned. The potential energy generation at a usage time of 8,000 hours (kWh/kW) is 218 TWh/a. Wind energy had in the mid of the year 2016 a power installation 43.6 GW and will have a prognosis of about 62.7 TWh/a end 2016. In the southern area of Germany the mean usage time is in a range of 1,200 to 1,550 h, in the middle area in the range 1400 to 1600 h and in the northern zone in the range of 1.700 to 2.000 h [6].

Seen from the transmission grid which was developed in the 1970's for the integration of large sized nuclear power plants with a security margin, the installed wind power has now reached the capacity limits of the available transmission capacity.

III. Low wind technology

The ratio of annual energy harvesting to the installed generating capacity has for nuclear power the value of about 8, for offshore wind and run-of-river-hydropower about 4 and for wind in Germany in mean only 1.5. This has the consequence for high investments into grid extension at low time of usage by wind generators.

In future it is necessary to improve this harvesting ratio for the onshore wind generation to enable cost efficient grid infrastructures. The following technological measures can help to reach this target:

- Increase the height of the tower
- Enlarge the rotor diameter
- Reduce the power of the wind generator

The following measures in the field of installation can be successful:

- Make installations in area with higher wind potential, e.g. on top of hills or in flat areas
- Take care of adequate distance between wind generators

In fig. 1 a comparison of different wind technologies is shown. Offshore wind with usage times of 3,500 to 5,000 kWh/kW shows good performance. But it is located far away from the bulk areas and needs development of the transmission grid.

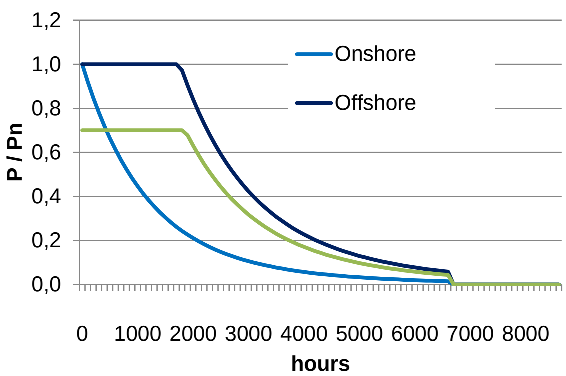

Figure 1 Ordered annual power-duration curves [2]

Onshore wind generators in traditional design show values between 1,300 and 2,700 kWh/kW. Here the mechanical power of the rotor *P* at nominal wind speed of about 12 m/s is equivalent to the installed generator power *Pn*. They use the installed transmission capacity above the value of 70 % of the installed generation capacity only short in a range of 200 to 300 hrs/a.

Finally, wind converters in low wind design (green curve) have a nominal rotor power at rated wind speed which is above the installed generating power. At adequate design onshore about 3,000 kWh/kW are achievable. As the generating power is limited, the need for grid extension is much smaller and the usage time of the installed grid capacity higher.

IV. The area law of decentralize wind integration

Wind converters have reached more than 30 years of development. At the beginning small generating power of below one MW was the standard. These small sized wind generators could be easily integrated in the existing electricity grid. As there was no specialized grid extension necessary the grid integration was in many countries free of charge.

In future wind generation will go above the 10 MW generator margin and large wind parks have to be interconnected. As the security margin of the transmission grid in Europe is already exhausted for wind integration, in future large wind parks need large grid extension. In some countries the integration is still free of charge. In some countries a one-time-only fee according to the installed wind power has to be paid, e.g. in Austria 150 €/kW.

In future it seems to be favorable to give subsidies for wind integration in the grid and for the wind converter investment itself. For this purpose a modelling approach has been developed. Here in decentralized organized energy cells a high degree of energy balancing will be achieved by decentralized use of the wind energy. This reduces the need for grid extension. High local demand at flexible peak demand balancing results in low distance for the transport of the wind energy. This forms a new target for the grid development. The total cost for wind integration are formed by the generating cost for the wind energy and the costs for grid extension. Fig. 2 shows a decentralized modelling approach where the wind generators are installed in vicinity of the end users. In this simplified model the wind generating area is describes by a circular generating area with a radius of r_W. The surrounding load area has the radius r_L. The maximum of the transport distance for the wind energy is given at the lowest load density and the highest wind generation density.

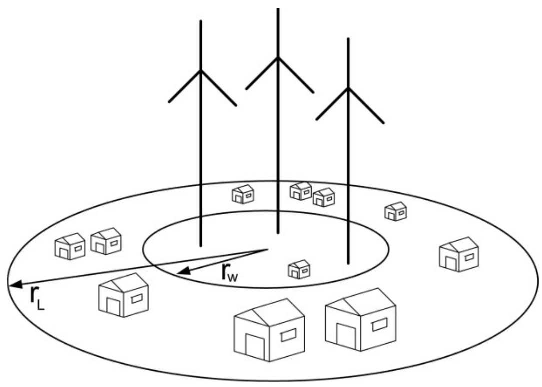

Figure 2 The area law of wind energy integration [2]

V. TOTAL COSTS OF WIND GENRATION AND GRID EXTENSION

In the following the costs of grid extension are evaluated according to the annual time of usage. Specialized grid extension, which is only used during the generation peak of some hundred hours per year has higher specific grid costs than basic transport costs. This allows comparing onshore wind integration in standard design and for low wind design.

Standard wind converters have today total installation costs of about 1,300 €/kW. Low wind converters need reinforced tower and footing according to the larger dimension and weight of the rotor, which is estimated to 2,700 €/kW. Taking a lifetime of 20 years and an interest rate of 3 % the generating cost for standard wind converters are 0.0446 €/kWh and 0.0625 for low wind generators.

The standard converters in this example have a usage time of 2,000 kWh/kW and the low wind generator 3,000 kWh/kW. Because of the higher usage time the higher installation costs are partly compensated.

Now also the grid integration cost shall be considered. In standard design the grid connection has to be dimensioned for the peak generating power, if no temporary shutdown because of grid congestion should be allowed.

In standard design rotor and generator have a nominal power of 3 MW. For the low wind design only the installed generation power is also 3 MW but the rotor has 8 MW. This results in a usage time of 3,000 kWh/kW and thus in lower specific grid costs. Fig. 3 shows the total costs of both variants.

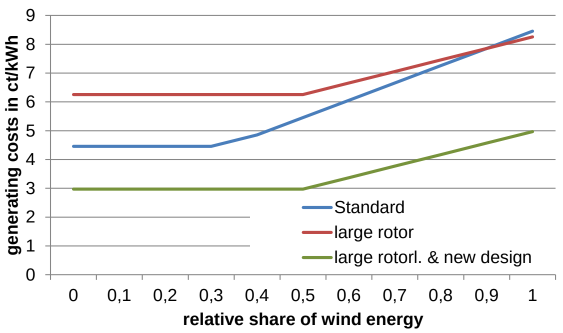

FIGURE 3 TOTAL COST OF GENERATION AND GRID [2]

For wind converters in standard design up to a 30 % portion of wind energy integration is possible without grid extension (horizontal blue line). At a higher portion the grid extension costs grow according to the mean usage duration.

For wind converters in large rotor design today a portion of 50 % of wind energy can be integrated without grid extension. The generating costs are higher according to the higher specific investment costs. But the grid extension costs show a lower gradient according to the higher usage time. At a grid loading of 80 % by wind energy a break-even point of both technologies can be seen. This means for low wind technology higher investments for the wind converter and lower grid extension costs compensate themselves.

In future by new design of wind converters by lightweight technologies the costs for tower and founding can be reduces. Here an example is shown, where the specific investment costs for low wind technology are equivalent to standard design, giving overall low wind generation costs of 0.03 Euro/kWh (green curve in fig. 3).

VI. CONCLUSION

The extension of the electrical grid according to the installed power of large wind parks forms in densely populated Europe some problems of acceptance by the population. This can in future hinder the adequate development of wind energy according to the long term European targets for renewable energy development.

In future component funding should be replaced by system funding and looking at the total costs and environmental impacts. In this context low wind technology and lightweight converter design will form in future a possibility to overcome the retardation of renewable development.

REFERENCES

[1] „Status of onshore wind energy in Germany,“ („Status des Windenergieausbaus an Land in Deutschland“). Deutsche Windguard 2016.

[2] G. Brauner, “Energy systems: renewable and decentralized – strategies for the energy turnaround,“ („Energiesysteme: regenerativ und dezentral – Strategien fuer die Energiewende“). Book in German, Springer 2016

[3] Umweltbundesamt, „Potential of onshore wind energy in Germany,“ („Potenzial der Windenergie an Land,”) Study document 2013.

[4] Deutsches Atomforum, „Decomissioning and removal of nuclear power plants“, “Stillegung und Rückbau von Kernkraftwerken,” German nuclear forum 2013.

[5] EU 2015/1222, “Commission regulation (EU) 2015/1222 of 24 July 2015 establishing guidelines on capacity allocation and congestion management,” L 197/24, 25.07.2015.

[6] BDEW, “Renewable energy: numbers, facts and graphics (2016),” “Erneuerbare Energien und das EEG: Zahlen, Fakten und Graphiken (2016),” BDEW Bundesverband der Energie und Wasserwirtschaft 2016.