WIND ENERGY REPORT GERMANY 2014

Special Report

BALANCING POWER FROM WIND TURBINES

Malte Jansen, Dominik Jost

Introduction

During the course of the energy transition in Germany, more than 25% of electricity consumed is now provided from renew-able energies. This energy comes primarily from wind turbine and photovoltaic installations. It is therefore becoming increasingly necessary that renewable energies are also involved in the provision of system services. The reform of the REA (Renewable Energy Act) has meant since the start of 2012 that renewables are able to participate in the market. This explicitly includes participation in the markets for the provision of system services. Within this context, balancing power is already being provided successfully by biogas and hydroelectric power plants (exceeding 1 GW in total). Wind turbines have yet to contribute any balancing power however. This is mainly because the formalities for the balancing service market are not rendering participation possible.

Since 2014, all renewables together provide more energy than any other power generation technology [1]. Renewables therefore represent the greatest pillar of German energy supply. The resultant responsibility for reliable operation of the energy supply system can only be perceived up to a point given the exclusion of fluctuating renewable energy. Despite these circumstances, the industry is aware of the problem and is proactively seeking solutions. For example, European energy supply company Trianel announced in 2014 it would be addressing this issue in 2015. The findings from the research project headed by Fraunhofer IWES are finally being implemented in practice.

Challenge of the electricity market design

Minor adaptations to currently applicable market conditions are being discussed to facilitate participation of fluctuating feed-in of renewable energy. This is attributable not least to the Green Paper / White Paper process of the federal ministry for economic affairs and Energy (BMWi). In the adaptation of market regulations, the needs of volatile generators must be addressed adequately without at the same time restricting the opportunities of existing market players.

An equitable balancing power provision with all types of balancing services with fluctuating feed-in of renewable energy would be unparalleled in Europe. Thus far there have been few regulations in Europe which open up access to individual system service markets for fluctuating feed-in of renewable energies. In Denmark, wind turbines are already providing balancing energy, but access to the reserve power market remains protected. In Ireland, wind turbines provide primary spinning reserve by accepting energy losses. Changing market conditions to benefit fairer competitive conditions for all players represents a new challenge for operators, wind turbine and virtual power plant manufacturers, and direct sellers. Many technical innovations have already resulted from this situation and are still being anticipated. Such an integration of renewables not only does justice to the pioneering role of Germany, it also substantially strengthens the competitiveness of companies in the international context.

This issue after all is about continuing the energy transition in its very nature. Part of this is the gradual flexibilisation of installations and the reduction of "must-run" power plants. Must-run generation, only on the grid to render system services, can be reduced significantly with the greatest possible provision of balancing power from renewable energy. The analyses in [2] arrive at the conclusion that the must-run generation of thermic power plants is up to 13.5 GW for the provision of balancing services. According to another expert's report [3], this must-run generation is between 8 and 25 GW. A capacity in the energy system which cannot be addressed constantly with renewable energy is therefore a reason to regulate renewable energy installations (especially for high feed-in levels from the fluctuating feed-in of renewables). Paramount in the provision of balancing services from renewables is the fact that there is a high requirement for balancing energy when feed-in levels are high, something which in addition could increase must-run load.

Balancing energy from wind turbines R&D project

In order to enable the integration of fluctuating renewables into the energy supply system, the Fraunhofer Institute for Wind Energy and Energy System Technology IWES carried out the "Balancing power from wind turbines" project. The project was run in collaboration with wind turbine manufacturer Enercon, wind farm operator Energiequelle and transmission system operators (TSOs) Amprion und TenneT. The goal of the project was to develop and test a concept with which wind turbines can provide balancing power cost-effectively. The project was completed in 2014 [4].

The process developed in this project shows the degrees of freedom and restrictions with which wind turbines can participate in the balancing power market. The focus is placed on bid preparation and trialing of a new verification method for rendering balancing power. At the end, the technical feasibility of the newly developed verification method was demonstrated in a field test.

The findings show that it is possible to offer day-ahead spinning reserve reliably with wind turbines. The technical realization of the verification method requires further research. The field test as part of the "Spinning reserve from wind turbines" project showed that both ICT environments and installations themselves are essentially capable of meeting the requirements. The obstacles pertaining to installation connectivity and activation could be overcome in the project. This process is likely to be structured more efficiently with commercialization.

Probabilistic forecasts create reliability

The participation of wind power in the balancing services market requires that wind turbines offer spinning reserve with the same reliability as existing suppliers. In Germany, a reliability of 100% is required from participants in this spinning reserve market. This stipulation cannot be met by any technical system however. A reliability figure of at least 99.99% for rendering spinning reserve can be derived from empirical values available from the TSOs.

The purpose of calculating a reliability figure is to facilitate quantification of uncertainty in a bid, and thereby to guarantee that the spinning reserve actually held in reserve is below the quantity offered in only 0.01% of cases. Probabilistic forecasts are a potential tool for determining the reliability of bids from wind farms and manageable installations. These forecasts return a wind farm or wind farm pool capacity which is attained or exceeded with a specific probability.

Shown in figure 1 are the results of a probabilistic forecast for different scenarios. The reliability figure is 99.994% for the entire German wind farm pool. The nominal capacity is normalized to 1. The orange line shows the result of the probabilistic day-ahead forecast - as balancing power which can be offered. The blue line is for the 1-hour intraday forecast. The red line is the actual feed-in level. Infringements of balancing power bids by the day-ahead forecast would always be detected by an intraday forecast. This increases forecast reliability even further.

The use of probabilistic forecasts opens up new areas of business for direct sellers and forecast providers. The provision of balancing services is just one aspect. The expectation is that information gained can also be used for issues of portfolio assessment, meaning the advancement of renewable energy system integration.

Verification method

A key issue in the provision of balancing power is the mechanism to verify the feed-in of balancing power when it is required. The current method, used by biogas installations and other spinning reserve providers, can only be deployed with restrictions for wind turbines. The call-off of negative tertiary control power is used below to explain the problem.

For manageable installations, the schedule registration is used for verification of spinning reserve rendering. The assumption is that the schedule is attained reliably. The call-off of spinning reserve is verified by comparing the actual feed-in with the planned feed-in from the schedule. Verification is achieved if the difference corresponds to the spinning reserve requested.

Keeping to the schedule is a problem for wind turbines. Although wind turbines have systematically reduced their balance compensation errors since the introduction of direct selling, it cannot be assumed that individual wind farms keep a constant value over 15 minutes. This is regarded as problematic, especially at times of strong wind gradients.

For a wind turbine to reliably keep to a schedule, it must be curtailed. The degree of curtailment determines the reliability of the schedule value. The principle of verification with the schedule is shown in Figure 2. The forecast normally used for direct marketing is shown in dark green. However, a wind farm keeps balancing energy in reserve in the first quarter of an hour, and so is regulated to the reliable schedule value of the probabilistic forecast (in blue). The energy shortage quantities are factored into the bids for the spinning reserve market as opportunity costs. This can quickly make the provision of spinning reserve uneconomical. Furthermore, the regulated energy must be replaced by fossil fuel plants. When a curtailment is carried out, the turbine power is reduced by an amount equaling the balancing power bid to a value below the schedule which is already curtailed. The level of the curtailed energy in provision is strongly dependent on the forecast quality.

There is an alternative method for verification of balancing power without the need for curtailment. During provision, the wind farm is operated as in normal direct selling. During the call-off, the wind farm is operated with differential capacity up to the maximum possible feed-in level. The maximum possible feed-in level is the power which would have been fed in if the wind farm was not regulated. With this verification, the installations would only regulate energy in the event of a call-off. The determination of possible feed-in level currently represents a technical challenge however, and it is being addressed by researchers and turbine manufacturers. Shown in the same way in Figure 3 is the verification mechanism using the possible feed-in level.

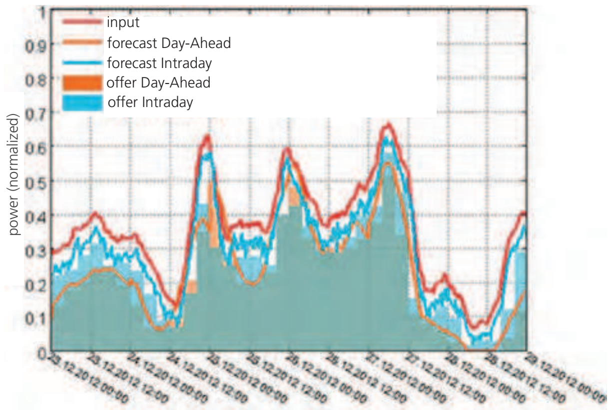

Figure 1: Probabilistic 1-hour forecast the 30 GW wind farm pool in 2012.

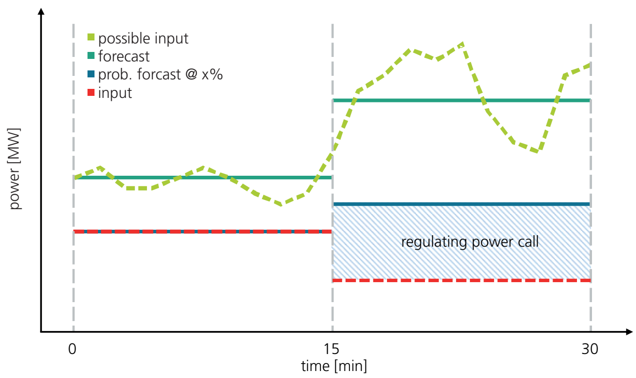

Figure 2: Verification of rendering negative tertiary control capacity using the "Schedule" verification method

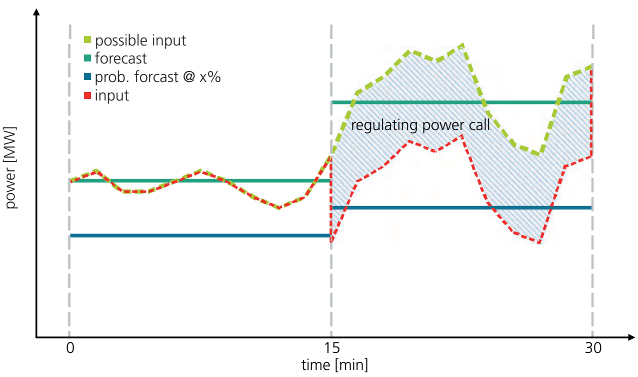

Figure 3: Verification of rendering negative tertiary control capacity using the "Possible feed-in level" verification method

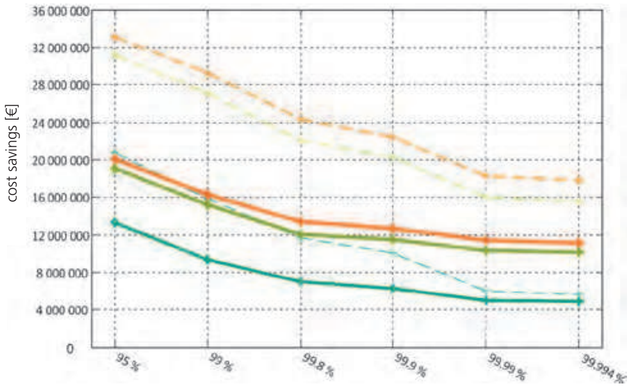

Figure 4: Savings effects and potential additional revenues for wind farm operators through participation by German wind farm pool in negative tertiary control market in line with "Potential feed-in level" method for different product lengths and reliabilities of bid for 2010

Business case for balancing service provision

Prices on the balancing power market could change if the framework conditions for participation of wind turbines are adopted such that a business model for wind turbines results. This means balancing power costs in the system fall without reliability being impacted. The reduction of costs for provision and call-off of balancing power arise through the participation of wind farms on the balancing services market. Expensive suppliers are ousted from the merit order list.

The economic effects of participation were addressed in the "Spinning reserve from wind turbines" project using simulations for a 30 GW wind farm pool [4]. The levels of wind farm bids are determined in each case using probabilistic forecasts. The level of savings for the system and potential additional revenues for suppliers depend on the framework conditions in question particularly on the issue of the verification mechanism.

Figure 4 shows the savings effects for participation of the German wind farm pool on the market for negative tertiary control in line with the "Potential feed-in level" method for 2012. Savings effects anticipated are shown as continuous lines. Potential additional revenues for the wind farm operators from the anticipated profits due to participation of wind turbines in the balancing power market are shown as dashed lines. In a comparison, the "Potential feed-in level" method is proven to be economically superior.

A savings potential of €13 million would have resulted for 2012 given a reliability figure of 99.994% and product length of 1 hour. Savings would be €12 million and €7 million for a product length of 4 hours and 24 hours respectively. The potential additional revenues in 2012 are €22 million (1 hour), €19 million (4 hours) and €9 million (24 hours). This means the benefits determined for 2012 as the total savings and potential addition revenues was €31 million, given a realistic assumption of a balancing power block with a length of 4 hours.

Summary

The growing share of fluctuating renewables within the energy system is increasing pressure on decision-makers to transfer more system responsibility to renewable energy. The remit first of all is compensation of very short-term system imbalances. Within this context, it has been possible for wind turbines to prove their capability of performing in a system-supporting manner. In order to ensure fluctuating renewables are also capable operatively it is essential to set the course correctly. Not least, the adaptation of market conditions by the Green Paper process of the federal ministry for economic affairs and energy is being addressed on a political level. The dynamics in technological innovations resulting from this change are directly linked to Germany's pioneering role in energy system transformation.

Sources

[1] [1] AG Energiebilanzen (2014). Accessed on 20/01/2015 by: www.ag-energiebilan-zen.de/index.php?article_id=29&fieName=20141216_brd_stromerzeugung1990-2014.pdf

[2] [2] Grünwald, R.; Ragwitz, M.; Sensfuß, F.; Winkler, J. (2012). Regenerative Energieträger zur Sicherung der Grundlast in der Stromversorgung – Endbericht zum Monitoring. Office for technology impact assessment at the German Bundestag. Berlin

[3] [3] Forschungsgemeinschaft für Elektrische Anlagen und Stromwirtschaft (FGH) e. V.; CONSENTEC; Institute for Electrical Installations and Electricity Industry (IAEW) at RWTH Aachen (2012): Study to determine the technical minimum generation of conventional generation system to guarantee system stability in German transmission networks given high feed-in levels from renewables. Mannheim/Aachen

[4] [4] Brauns, S.; Jansen, M.; Jost, D.; Siefert, M.; Speckmann, M.; Widdel , M. (2014). Balancing energy from wind turbines - final report. Kassel, http://www.energiesystemtechnik.iwes.fraunhofer.de/de/presse-infothek/publikationen/uebersicht/2014/abschlussberichtregelenergie-durch-windkraftanlagen.html