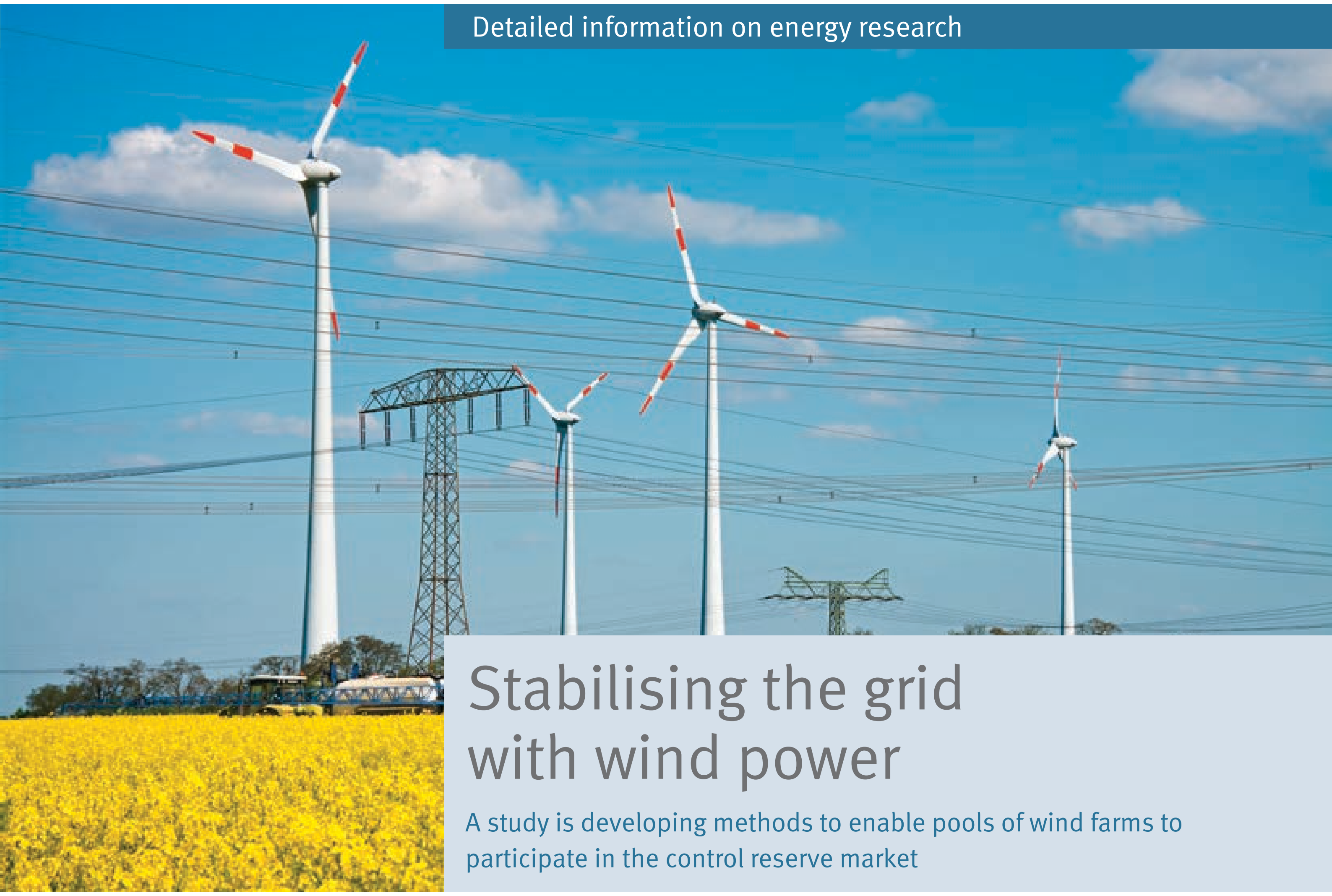
**Projekt**info **08**/2014

Detailed information on energy research



# Stabilising the grid with wind power

## A study is developing methods to enable pools of wind farms to participate in the control reserve market

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*In future it is intended that photovoltaic systems and wind farms contribute more to the stability of the electricity grid. They could then replace some of the fossil fuel capacities that until now have had to be used for the sole purpose of balancing out frequency variations. In a study, methods have been developed that can be used for intermittent renewable energies when bidding to supply control reserve as part of regular tendering periods. In addition, the study is also concerned with developing procedures for verifying the provision of the power. In future a pool of wind farms will be able to provide part of the control reserve required in the German electricity grid.*

Electricity always needs to be generated in the moment when it is required by loads. The electricity grid requires a balanced ratio between production and consumption at all times. It must reliably maintain a frequency of 50 Hertz in Europe with fluctuations that are as small as possible. In Germany this stability is provided by the four major transmission system operators. They are responsible for balancing out variations between generation and consumption. In order to balance out temporary production surpluses on the one hand and the temporarily higher demand for electricity on the other, the system requires reserves for restoring the nominal grid frequency. This system service is called control reserve and is traded in different qualities and special auctions. With the introduction of direct marketing, the reform of the 2012 German Renewable Energy Sources Act created the legal provisions enabling wind farms to participate in this market.

This research project is funded by the

Federal Ministry for Economic Affairs and Energy (BMWi)

In collaboration with industry partners, the Fraunhofer Institute for Wind Energy and Energy System Technology IWES has developed methods that in future will enable wind turbines to provide control reserve. The first component is a tender process that enables operators to participate in the auctions. Using probabilistic forecasts that combine a capacity with a probability, several wind farms can calculate their possibilities together as a pool. This primarily involves the minute reserve power that must be provided on a quarterly hour basis and is re-tendered on workdays. It is also known as tertiary reserve. The second component is a method for verifying the provision of control reserves that is suitable for intermittently fed renewable energy. In the later billing it needs to be differentiated between how much control reserve was only offered by the wind farms and how much control reserve was actually activated. Compensation and remuneration for services rendered are already being paid in the market for this purpose. For this verification, the researchers compared two different systems. The first system provides verification using the scheduled generation as a reference value. The second system uses the grid feed-in that would have been possible by the wind farm as a reference for the verification.

## Providing wind power reliably

One of the central issues of the study was concerned with the reliability that needs to be guaranteed by control reserve providers. Theoretically, the power plants involved should provide a technical reliability of 100%. However, since technical systems can fail, a reliability of "only" 99.994% was assumed for the project based on values gained from practice. This requirement must also be met by bidding wind farms and, if required, they must completely supply the control reserve offered. On the one hand wind farms have a high level of flexibility, since they are fast and can be precisely regulated. On the other hand, however, there is considerable dependence between the wind speed and the amount of electricity generated. The key question therefore is how securely and how far in advance can the wind conditions be forecast? The wind farm's possible contribution to the control reserve under these conditions needs to be calculated in advance.

For this purpose, probabilistic forecasts are used to quantify the risks. They indicate the probability that a target value will not be met or will be exceeded. Two statistical calculation methods and one based on physical parameters are used here.

In order to enable wind farm operators to participate in the auctions for control reserves, the existing rules need to be modified. In regards to this already ongoing discussion on reform, the study highlights various possibilities provided by wind power under various conditions. Depending on the season, wind farms can offer control reserve with the same reliability as other power plants if the auctions take place on the day the capacity is provided (intraday) or no more than one day in advance (day-ahead). However, only large pools of wind farms that are sufficiently distributed in spatial terms have a realistic chance of successful participation. This would mean that the existing ban prohibiting pooling across control zones would have to be lifted. The possibilities grow with increasing pool size, shorter auction periods and smaller production periods, i.e. if control reserve was to be tendered in future for one instead of four hours.

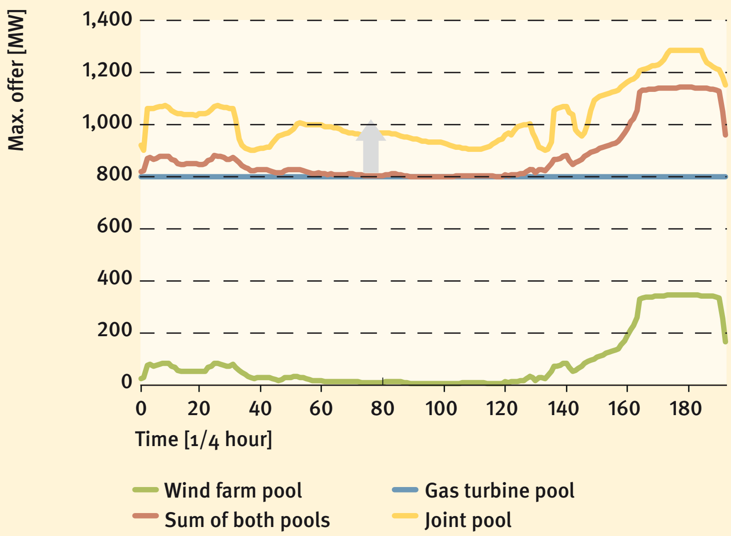


Fig. 1 *The green line shows the potential amount of control reserve that can be offered by the wind farm with a reliability of 99.994% and the blue line shows the potential amount that can be offered by gas turbines with the same reliability. The red line shows the potential when both offer control reserve separately. If both are mathematically folded together, a pool of wind farm and gas turbines can offer more control reserve than separately (yellow line).*

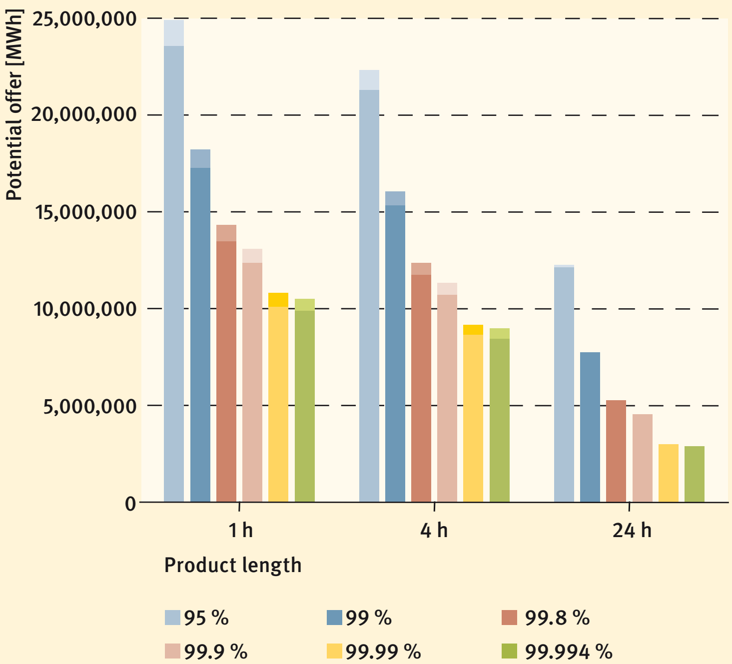


Fig. 2 *The image shows the potential provided by a 30-GW pool consisting of all German wind farms. The tendered length of the capacity (product length) and the required reliability are decisive factors for the size of the available capacity.*

This especially applies to negative minute reserve power, with which wind power would currently have the best chances at the auctions. For about 3,500 hours a year, a pool of all German wind farms could provide at least 100 MW, and could alone supply the tendered negative minute reserve for 1,700 hours a year. No bids can be made in more than 5,000 hours. Pooling between wind farms and controllable systems (for example gas power plants) also offers interesting possibilities. Together they can offer more power than separately (Fig. 1).

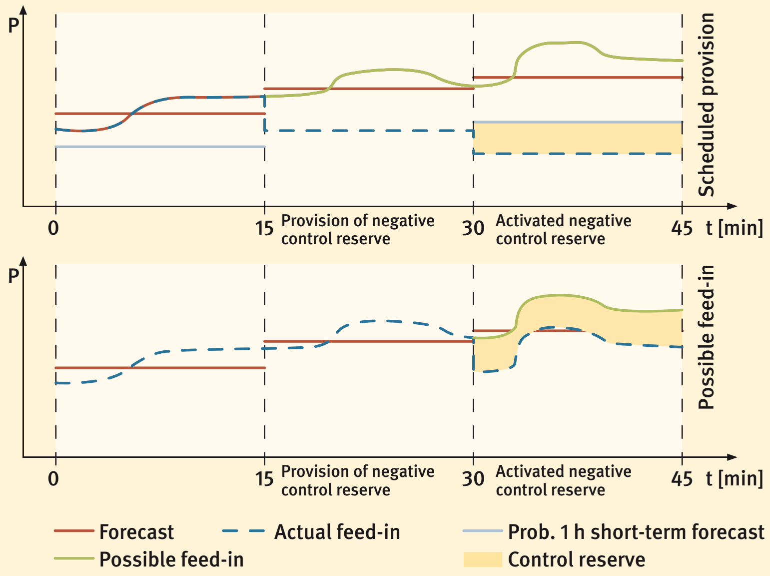


Fig. 3 *The illustration shows the two verification methods in an example for negative control reserve power. When comparing the two methods it can be seen that more wind power (blue dotted line) is used with the "possible feed-in" than with the scheduled provision. This is mainly due to lower losses in the provision phase.*

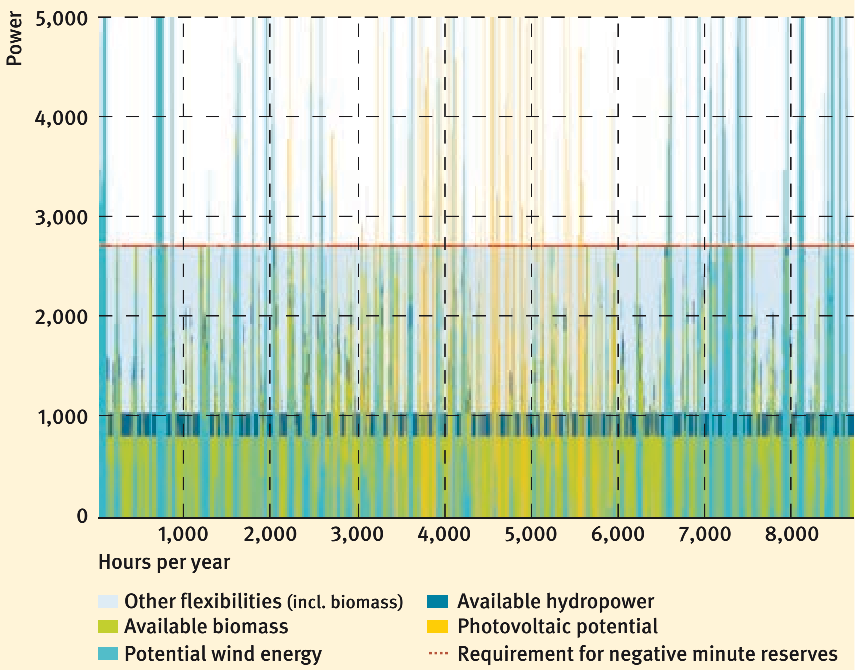


Fig. 4 *One possible scenario showing the extent to which two 30-GW farms comprising wind turbines and photovoltaic systems can contribute along with other renewable energy sources to the control reserve in Germany. This assumes that there are no market restrictions.*

## Providing verification

The researchers have worked with two verification methods: verification based on the "scheduled generation" and verification based on the "possible grid feed-in". Both procedures can be handled with the same security. The scheduled generation method has been standard until now for conventional power plants as well as for biomass and hydropower plants, whereby the control reserve providers derive their target values from the scheduled generation requirements. If control reserve is requested during this time, only the difference to the scheduled generation applies for billing purposes and not the difference to the potential possible capacity. In the "possible feed-in" verification procedure, on the other hand, the calculation is based on the value that the farm would have achieved if it had not been throttled for the control reserve. For wind energy, the second method provides both economic and environmental advantages. However, the application of the new method depends on changes to the existing regulations.

All project partners are in favour of gradually opening up the control reserve market to wind energy, as well as in having shorter tendering times and product life cycles. They view this as an opportunity to gradually integrate their joint experience into the concept. However, in terms of recommending the procedures, the respective advantages and disadvantages of the two methods are weighted differently. One group advocates the "possible feed-in" method, whereby they point to the goals of maximising the contribution made by wind energy and temporarily deactivating more fossil plants while still guaranteeing grid stability. The other group prefers the "scheduled generation" method. They argue that wind power is only seasonally available, but the control reserve market has to function throughout the year. They also point to the greater mathematical and organisational effort required with the "possible feed-in" method.

## International perspectives

The study also sheds light on the national strategies in eight countries that currently have a high proportion of wind power. In these countries there are similar discussions and plans as in Germany. Wind farms are already contributing to control reserves in the UK, Denmark and Ireland.

With regard to the international market and the high proportion of exports, German wind turbine manufacturers are calling for a common European standard for control reserve. They want to avoid having to adapt the wind turbines to accord with different national features.

## Control reserve supports the grid

The need for control reserves can be caused by both generators and loads. This control reserve is available as an activation reserve. If power plants temporarily generate too much electricity or if large loads are suddenly curtailed (e.g. electric steel plants), then the grid requires negative control energy from this available power. Either part of the power plants that previously submitted offers in this regard are throttled or additional loads are activated (e.g. pumped storage power plants are charged). Vice versa, with positive reserves either greater electricity production is required or large loads have to be removed temporarily from the grid. All forms of control reserves are traded via the www.regelleistung.net platform with varying lead times. All providers must complete a pre-qualification process in order to prove their reliability. In 2013, 43 providers in Germany were equipped with this authorisation.

## Renewables supporting the grid

In addition to wind energy, the results of the study also apply to photovoltaics (PV). However, the latter currently still has to solve further tasks in terms of the grid stability. Until now, the inverters used in the roughly 400,000 large- and medium-sized PV systems in Germany have been configured so that they switch off synchronously as a precaution at a frequency of 50.2 Hertz. Given the meanwhile very high solar power injection over periods of several hours, this simultaneous down-regulation of the photovoltaic systems involves the risk that the grid frequency will drop too low as a result. In the worst case this could cause a blackout. Therefore in Germany all inverters will be converted by the end of 2014. In future when the grid frequency rises above 50.2 Hertz, they shall gradually lower the power fed into the grid and then gradually switch themselves on again according to the requirements of the grid. Among renewables, biomass and hydropower plants – whose contribution to the power supply does not fluctuate – are already contributing up to 1,050 MW to the control reserve. They are easily adjustable and can work under the current market conditions.
A further option for renewable energy technologies is the combination of various systems and technologies to create virtual power plants. These can, for example, consist of a combination of wind turbines, photovoltaic systems, biomass and hydropower plants, as well as storage technologies. Such a concept has been tested, among others, in the rural district of Harz. The individual systems' various phases of too high and too low outputs are therefore balanced out internally. Compared with the national electricity grid, a virtual power plant acts as a single large power plant and can thus better maintain the target frequency.
Greater temporal flexibility in terms of the consumption can also help to place the temporary production peaks from renewable energy sources in the market. Flexibility options can be enabled, for example, through intelligent communication between the grid and individual loads. Energy services that to a limited extent can be varied time-wise, such as refrigerating or washing operations, can be shifted into periods with surplus electricity. The last component is the expansion of storage capacities. At the national level, the Energy Storage Funding Initiative is aiming to further develop a wide range of storage technologies for electricity, heat and other energies.

## Project participants

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## Links and literature (in German)


- www.regelleistung.net | www.forschung-energiespeicher.info | www.forschung-stromnetze.info
- Brauns, S.; Jansen, M. ; Jost, D. u. a. : Regelenergie durch Windkraftanlagen. Abschlussbericht. Förderkennzeichen 03241V6179. 2014. 166 S.
- Jansen, M.: Optimierung der Marktbedingungen für die Regelleistungserbringung durch erneuerbare Energien. Kurzstudie im Auftrag des Bundesverbandes Erneuerbare Energien e. V. und der Hannover Messe. 2014. 46 S. The document is available in the service area for this Projektinfo brochure at www.bine.info.


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## Imprint


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**Project number**
03241V6179

**ISSN**
0937 - 8367

**Publisher**
FIZ Karlsruhe · Leibniz Institute for Information Infrastructure GmbH
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Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag