RAVE – A MILESTONE IN OFFSHORE WIND ENERGY RESEARCH

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Summary

Offshore wind power is expected to expand rapidly in Europe over the next years and decades. However, the developing industry still faces many challenges. Most prominent challenges are the lowering of the technological risk and the reduction of the cost of energy. Industry and research organizations have to cooperate in research, development and demonstration to overcome these issues. The German research initiative RAVE is an example for successful collaboration: The first German offshore wind farm alpha ventus, its function as a test site, and 33 accompanying RAVE research projects delivered outstanding results as well as very good production and availability figures. The 33 RAVE research projects have delivered a wealth of results, of which some have already been transferred into industrial use.

1. Introduction

1.1 Offshore wind power expansion targets

Offshore wind power (OWP) is a centerpiece of the German energy policy. The government's target is to reach 20-25 GW of OWP capacity installed by 2030 [BMU 2002]. A similarly rapid expansion is expected in Europe. The European Wind Energy Association EWEA estimates an installed capacity of 40 GW by 2020 – roughly a tenfold increase compared to the present state [EWEA 2012]. This would lead to a share of about 4% in the European electricity consumption.

1.2 Technological risks and challenges

The planned rapid expansion of OWP is mainly driven by political aims. To realize it, many challenges have yet to be met. The rapid expansion of offshore wind farms will require hard work, and the experience with the technology is still limited.

Reducing the technological risks is probably the most important challenge in this development. One reason are the harsh environmental conditions under which offshore wind farms have to operate for 20 years and more. These conditions restrict the turbines' accessibility which in turn can cause very high costs for almost any technological failure due to possible extensive downtimes [Fraunhofer IWES 2012].

Another important challenge is cost reduction. As expected, the cost of electricity generated by OWP – a very young renewable energy technology - is still very high in comparison to wind power on land [EWEA 2009]. In order to make OWP a socially accepted and economically successful substantial part of the energy supply, a reduction of its overall cost is necessary. When looking closer at the cost of electricity from offshore wind farms, the wind turbine itself accounts only for about 1/3 of the total cost. The main part of the cost results from support structures, foundations, grid connection, installation and O&M. Solutions for these tasks cannot be adopted from onshore wind power technology. This is the reason, why there is no industry yet in Germany that can meet these needs. This is accompanied by a lack of highly qualified personnel to design, build and operate offshore wind farms. The development of a new industry is an important task on its own.

Grid connection and grid integration of OWP is a long-term task with many issues. Currently, the grid connection at sea is the bottleneck for the offshore development in Germany. The electricity transport on land from the coast to the load centers might become the next issue, if grid expansion doesn't proceed fast enough. Integration of a large, weather dependent electricity source into the electricity system is probably the most important challenge in the long run.

1.3 The role of research, development and demonstration

Clearly, the technological risk has to be reduced. This could be done, for example, by experience over a long time. The alternative is to better understand the technology by carrying out research, development and testing activities. The erection of test facilities for blades, materials, support structures, nacelles etc. is clearly a step towards this direction. Equally important is the improvement and expansion of knowledge in areas such as the design of turbines and components, design conditions and loads, as well as the effects of loads on components.

Research, development and demonstration (R,D&D) are key factors for reducing the cost of energy as they speed up the optimization of the technology and pave the way for fundamental innovations. Examples for optimization tasks are the determination of the optimal turbine size, the drive train concept, robust materials and optimal production methods for rotor blades. Other R&D tasks, which might allow more fundamental innovations with a potential for larger cost reductions are e.g. the support structure and foundation, an area where still many different

concepts are used, as well as in installation methods and O&M logistics.
A special challenge of OWP is the need for innovative solutions on the one hand and the need for proven technology with a long track record on the other hand. In solving this apparent contradiction, research, development and demonstration will play the key role. The aim is in a first step to replace experience with simulations and models. A very important second step is the operation of test sites and demonstration projects which can help to transfer solutions from R&D into practical use. The German test site alpha ventus and the accompanying research initiative RAVE are one example for this.

2. The test site alpha ventus

Germany's first offshore wind farm alpha ventus was completed in 2009 and officially inaugurated in April 2010. Next to its commercial use, alpha ventus' main role is being an offshore research and demonstration test site. It is located in the German exclusive economic zone, about 45 km north of the island of Borkum and with a distance to port of about 75 km. The water depth is about 30m at the site. The wind farm consists of 12 turbines, each of them having a nominal power of 5 MW. Two different types of turbines (REpower 5M, AREVA Wind M5000) and two types of foundations (Jacket, Tripod) are used (see figure 1). Alpha ventus was planned, built and is operated by DOTI, a consortium of the three energy companies EWE, E.ON and Vattenfall.

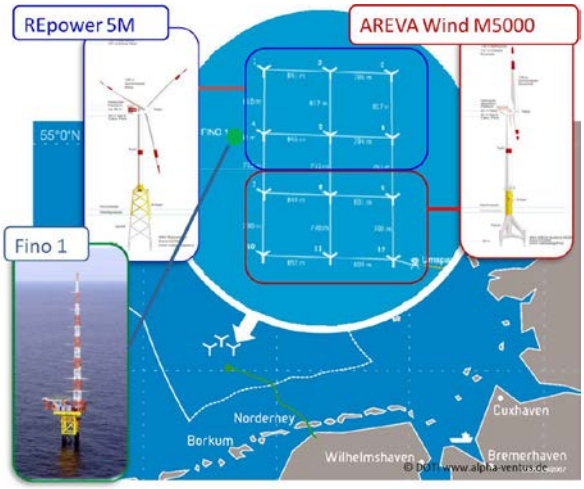

Figure 1: Location and layout of alpha ventus; also shown are the turbine types and the FINO 1 research platform (© artwork: DOTI; © picture: DEWI)

3. The research initiative RAVE

With substantial support of the German Environment Ministry (approx. 52 mill. €), a consortium from science, industry and administration has formed the interdisciplinary research initiative RAVE – research at alpha ventus. The aim is to find solutions for a number of challenging issues in relation to the utilization of offshore wind power. To date 33 projects have been carried out or are being carried out within the RAVE initiative, with more projects expected to start soon. More than 50 organizations and about 200 scientists are involved in the research activities. A close collaboration between the companies and research organizations has been established.
Two cross-cutting projects form the heart of the RAVE initiative: The overall coordination of RAVE is done in a dedicated coordination project led by Fraunhofer IWES. In addition, all measurements required for the research projects are performed by a central measurement service project led by the Federal Maritime and Hydrographic Agency BSH. This project makes the data available for accredited RAVE researchers in a central RAVE data base. An invaluable and unique data set of measurements has been created: Four turbines are extensively instrumented and further sensors are installed in the surrounding waters and at the offshore and onshore substations. Altogether more than 1200 sensors are applied (see figure 2).

Figure 2: Sketch of Repower 5M (AV4; left) and AREVA Wind M5000 (AV7; right) offshore wind turbines in the alpha ventus test site. Markers indicate locations and type of instrumentation used for the RAVE measurements. (© pictures: DOTI; Editing: Fraunhofer IWES)

RAVE projects have been addressing not only turbine technology, foundations, grid integration, and monitoring, but also environmental, meteorological,

geological, oceanographic and other research topics. An overview of the topics and projects can be found e.g. in the brochure of the RAVE initiative on the RAVE homepage www.rave-offshore.de. The research activities carried out in RAVE are also illustrated in a 50 minutes science documentary produced in 2011. The movie gives a vivid impression on the challenges of OWP and shows results of the RAVE research activities (see www.youtube.com/user/RAVEoffshore/feed).

4. Research results and experiences

The results of the RAVE projects have been presented in an international conference held in Bremerhaven in May 2012. Most of the approx. 55 presentations are available on the website of the conference www.rave2012.de. Results have also been presented at many other conferences and in journal papers.

The operational experience of the first years of alpha ventus is extremely positive. In 2011, with 4400 full load hours the production was to our knowledge the highest ever reported for an offshore wind farm. The availability of the wind turbines was very high, too: approx. 95% in 2011.

Apart from the research results, the RAVE initiative has also made valuable experience with Research, development and demonstration (R,D&D) at an offshore test site:

First, weather constraints were repeatedly underestimated throughout the project. Weather dependency of the work and the logistics led to delays in the erection of the wind farm and in the installation of the RAVE measurements (see figure 3).

Second, a crucial factor for the success of the RAVE research activities is the collaboration between all partners involved. It is by no means granted that competing companies or researchers share data and knowledge and collaborate trustfully. Especially in the collaboration between industry and research organizations the challenges were underestimated at the beginning. However, throughout the project a sound and trustful basis for collaboration was developed. This includes the development of an extensive set of cooperation and confidentiality agreements, such as the accreditation procedure of researchers for confidential data. Moreover, the continuous and close collaboration of all partners in the Steering Committee created a mutual understanding of each other's aims and constraints. Next to the common task and the willingness to compromise, this understanding was the key for the successful collaboration.

Figure 3: Picture of alpha ventus as it is most often shown (top), in normal weather conditions (center) and in severe conditions (bottom) (© pictures: DOTI, BSH)

5. Summary and outlook

The large scale utilization of OWP requires the development of a new industry sector. Offshore sites are not just another type of site for the existing wind industry. This new sector has many challenges ahead, of which the lowering of technological risks and the reduction of costs are most prominent. This requires proven technology and innovations at the same time. R,D&D can play a key role in solving this two-sided

challenge. A close collaboration between industry and research is a prerequisite for this.
The German research initiative RAVE is an example of the success of R,D&D through cooperation between industry and research organizations. The test site alpha ventus delivered outstanding production and availability figures in its first full year of operation. A new turbine class was demonstrated to operate reliably under extreme offshore conditions. The largest and most comprehensive measurement program at an offshore wind farm worldwide has delivered unprecedented full scale in situ data for model development and validation. Based on the measurement data, the 33 RAVE research projects have delivered a wealth of results of which some have already been used in the development of new turbine types, in the approval process etc. Moreover, a dedicated research community for OWP has formed which is capable of supporting the industry in meeting the challenges ahead.
In the future, R, D&D with real turbines at real offshore sites will continue to be necessary. Due to the rapid development of the industry, the turbines in alpha ventus soon will not be the latest technology anymore, and therefore new test sites will be needed. In other countries in Europe, test sites have been or are currently being developed as well (see figure 4 for some examples).
The aim of new test sites is to enable the industry to continuously demonstrate the latest technology, to promote innovative developments and to allow researchers to accomplish the knowledge needed for the future. To this end, the collaboration between research and industry, but also within the industry, will have to be intensified nationally and internationally. RAVE can be seen as a first step on this way.

Figure 4: Offshore wind power test sites or prototypes in Europe (examples only) (© Fraunhofer IWES)

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RAVE science documentary: