Summary of the Workshop Science & the Energy Challenge on Offshore Wind, Part 1
20 May 2014, Centrum Wiskunde & Informatica (CWI), Science Park 123, 1098XG Amsterdam

Opening: Jeroen Witteveen (CWI)

The CWI is the national scientific research center on mathematics and computer science of the Netherlands Organization for Scientific Research (NWO). Its mission is the discovery of knowledge and the transfer to society and industry including energy topics. Multiple groups are working within the energy theme on computational fluid dynamics, plasma physics, smart power grids, and biofuels. The goal of the workshop is to discuss the long-term European scientific challenges in offshore wind energy and to translate them to the strengths of the Dutch research environment.

The EAWE research challenges on offshore wind: Gijs van Kuik (TU Delft)

A discussion on the vision and priorities in long term research and development (R&D) is necessary, because wind energy is here to stay. Two European seminars have been held under the umbrella of the European Academy of Wind Energy (EAWE) about the challenges that demonstrably form specific and critical barriers that, if removed, would have significant impact for our understanding. The resulting EAWE report will appear later this year, of which half of the chapters relevant to the Dutch situation are discussed during the workshop.

Among the long term challenges are also the societal acceptance, legal and international aspects, storage, system integration, and the interconnection with other energy fields. The workshop focuses on topics that are specific to wind energy on the wind farm level.

Topic I: Aerodynamics: Carlos Simao Ferreira (TU Delft), Leo Veldhuis (TU Delft)

The challenge in rotor design is not the cost, but the range of scales in the Navier-Stokes (NS) equations for computational fluid dynamics (CFD). Other points of attention are Blade Element Momentum (BEM) methods, 3D unsteady aerodynamics, uncertainties, wake instability, and wake-wake and rotor-wake interactions. Points for airfoil improvement are 3D flow, transition and turbulence, flow separation, unsteady 3D boundary layer control, and alternative concepts such as vertical axis wind turbines and kites.

The alternative concepts are not fully used because of the basic effect of their maturity on the cost of energy. For example, kite control has a price compared to its aerodynamic simplicity. The question is whether the fundamental science of aerodynamics is done with the Navier-Stokes model and it is only about applications or it goes in cycles depending on available data. Propellers are reaching a different scale in which unsteady fluid-structure interaction (FSI) in stall conditions is important, for which experiments are unpredictable and the numerics is not finished. Both have limitations and ground tests are necessary. Important research lines are reliable separation control coupled with design at different scales with variability and production efficiency on the wind farm scale. Therefore, a larger framework of multidisciplinary design optimization (MDO) is necessary with a broad system approach based on fast codes and multi-scale models. Sensitivities determine whether local control and site specific support including type certification is the most efficient investment. Wind energy can learn from helicopter aerodynamics in terms of aerodynamic damping for the structure in the side direction by sideway pitching, dynamic control, and materials. However, another application also has specific challenges such as the 20-30% thickness of wind turbine blades.

Topic II: Hydrodynamics, Soil characteristics, Floating: Andrei Metrikine (TU Delft), Michiel Zaaijer (TKI WoZ)

Experience with offshore structures from the oil and gas industry can be applied to offshore wind. Suitable concepts for offshore wind are monopiles, jacket support, and floating. Challenges are the aero-hydro-soil-support-control interactions, soil characterization, pile driving, service life, corrosion protection, and currents and waves.

Offshore and wind energy communities can learn from each other. It is a matter of new designs versus validated ones, short-term responses versus long-term responses, and models versus data. It is necessary to use probabilities to reduce conservatism and change the standards. High waves are for example less probable. Measured statistics data is unavailable for the correlation and joint distributions of wind and waves. Computational fluid dynamics (CFD) can predict most forces, but not all phenomena such as ringing and it is too expensive in the design process. Floating may not be relevant for the Dutch market, but it is relevant for Dutch research and industry because their applications are global.

Topic III: Control and System Identification: Jan-Willem Wingerden (Duwind), Marco de Baar (DIFFER, TU/e)

New control technologies beyond pitch control are required to reach 20MW turbines at sea for decreasing loads and increasing energy output. Important aspects in the reliability of efficient smart control algorithms under uncertainty are actuators, local flow and structural sensors, model development, and communication on the increasing scale of the wind farm level with yaw wake control.

The capacity factor can moderately be increased up to 5% using control. One of the challenges is in the topology of centralized or distributed control and measurements. Earlier measurements are more effective, because feedback control is always after the fact. There may be a need for new sensors such as close range lidar versus measurements of the whole wind field. Reduced models of the physics and data are necessary for a fast system response. Other points of attention are the robustness against failures and fault tolerance, and the financial constraint and cost functions including a penalty for control actions.

Topic IV: Wind and Turbulence: Joachim Peinke (Forwind), Richard Stevens (John Hopkins University)

Basic research on wind and turbulence is necessary, because power conversion is a highly dynamical process since the resource is highly turbulent with extreme chaotic events from the meteorological scales to the micro scales. All these scales are of interest from forecasting and planning to structural loads. There is a significant difference between wind data, international standards for gust statistics, and incident wind fields. The ten minute average and variance as the basis for design and the mexican hat profile are not sufficient. These standard models are off in probabilities and the distribution, because there are more turbulent fluctuations in reality. For example, there are not always higher winds at greater heights instantaneously. It is a matter of the large turbine with large inertia versus the very fast and large fluctuations in the smallest atmospheric length scales relevant for wind farms. A better understanding is necessary whether the open problems of the Navier-Stokes statistics need to be solved first and what are the most relevant scales and parameters.

Turbulence is not taken into account by the standards for loads and power prediction, only means and safety factors are. The standards and norms are correct, but not complete for example for short gusts. Maybe there is a relation with unexpected failures because fluctuations are not good for the electrical parts and the gearbox, which are mostly repairable but that is more difficult at sea. To reduce conservatism a better understanding of the inflow is needed. Many fields need to be involved to solve this problem, e.g. instationary and inhomogeneous turbulence, cloud correlations in the atmosphere, physics, and travelling nonlocal waves caused by the wind. Knowledge of flow physics then needs to be translated to elastic and plastic responses to turbulence, where separate models are necessary for fatigue loading and extreme events. The interest is shifting from turbulence to wind turbulent statistics and to understanding what matters for the turbine.

Topic V: Materials and Structures: Rogier Nijssen (WMC), Rinze Benedictus (TU Delft)

For the application of composites, steel, concrete, soil, and electrical wires at sea we can learn from offshore oil and gas, aerospace, and chemistry. Important aspects are newly designed (bio-based) materials, their life cycles, joining and interfaces in hybrid structures, and the step from material properties to structural behavior. An overarching theme is insight into the short to long term time effects and micro to macro length scales, and the extrapolation of experimental uncertainty to long-term fatigue. Orders of magnitude are to gain in terms of safety factors and experimental underestimation. Promising techniques are multi-scale modeling and structural health monitoring of the road to failure by pattern recognition of cracks.

Experiments for fauling, erosion, and at different amplitudes are necessary, but they may be slower than in the field. Therefore, new modeling and virtual testing is required for the development of new classes of materials and topologies beyond the boundaries between fundamental research and applied needs. Low-cost wind turbines result in low-end materials and fast production techniques and this limits the introduction of new materials. There is a lack-of-knowledge in interfaces of multiple materials. There are opportunities in smaller sensors and in using energy from deforming materials and actuators.