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An optimal floating structure?

Are Kaspersen
DNV GL

Abstract:

Floating wind energy is moving closer to commercialization: the US, Japan and the EU all have ongoing demonstration projects, and the first full scale pilot parks are underway.

As floating wind is gaining significance, the number of new and innovative floating structure designs is increasing, aspiring to be more cost-effective and better than the competitors. DNV GL has gained unique insight into the industry working with most novel concepts. It is expected that when the industry matures, only a handful of the concepts will survive. Can we predict which? DNV GL will discuss some of the concepts out there, and discuss key parameters that will have to characterize the concepts that will survive and emerge as industry winners.

Going deeper – finding the optimal solution for each project

Since its deployment over three years ago, Statoil's Hywind concept has been tested very successfully, demonstrating a stunning capacity factor of nearly 50 % in 2011. US technology Windfloat was deployed outside the Portuguese coast during the fall 2011, and by this it became the world's first large scale floating wind energy prototype based on the semi-submersible technology. More initiatives are ongoing, including government funded programs in both the US, UK, France and Japan.

DNV GL will introduce the audience to the key technical concepts being developed in the industry - the spar-buoys, semi-submersibles and tension leg platforms (TLPs), as well as some dark horses. Each of these three fundamental concepts has its own characteristics, strengths and weaknesses, and in order to choose the optimal floating wind turbine structure, the developer will have to consider a number of important parameters, unique for his/her project. Based on the understanding of these different challenges, the optimal floating wind energy concept can be selected. This is vital for the project developer to become successful.

Based on studies DNV GL has executed for stakeholders developing floating wind technologies or projects, such as technical evaluations and qualifications (e.g. Hywind, WindFloat etc), technical and commercial benchmarking studies, and standard and rules development, DNV GL's paper will aim to present key learnings with regard to the three key philosophies' respective technical and commercial strengths and weaknesses, main cost drivers and development opportunities. Furthermore, DNV GL will present its benchmarking methodology for assessing the different technical philosophies and concepts.

To conclude the presentation, DNV GL will elaborate on our view on the key success parameters for a floating wind concept, as well as the cost of energy potential for floating wind energy in a future, mature market.

Blade Pitch Control of Floating Offshore Wind Turbine by a Modern Control

Ken Haneda and Toshiki Chujo
National Maritime Research Institute

Abstract:

Floating Offshore Wind Turbine (FOWT) is a complex system because its support structure and aerodynamic load due to rotor rotation affect each other.

Blade pitch control is one of the control system in a wind turbine and it aim to maximize power generation. But there is a possibility that the control system cause unsuitable motion of a FOWT according to the relationship between a motion characteristics of the support platform and rotor characteristics.

A wind turbine founded on land or sea bottom can be assumed as a single input - single output system. On the other hand, a FOWT system should be assumed as a single input - multi output system (SIMO system). The multi output means power generation and stability of the motion of the support platform. It is said that modern control system work well for the SIMO system and a FOWT with modern control systems may be effective.

In this thesis, the authors introduced LQ control, one of modern controls. Motion of a FOWT was linearized and the controller was designed as a linear system. Water tank test using a FOWT model with LQ controller was carried out. From the tank test and simulation, the controller was found to be effective for suppressing large motion in waves.

Model tests of the Floating Axis Wind Turbine (FAWT)

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Abstract:

Horizontal Axis Wind Turbine (HAWT) has been quite successful in onshore and bottom-fixed offshore wind farms. However, the situation may not be the same in the future floating offshore wind applications which have huge potential in deep water region. The present top-heavy design of HAWT requires a large float system to keep the upright position of turbine system. Since the floater part is about twice as expensive as that of turbine system onboard, cost reduction of the floating HAWT will not be easy. The maintenance work in the HAWT nacelle at the top of high tower will be also expensive because of the floater motion. In the expected high-wind condition of offshore wind sites, safety concerns of maintenance workers and the narrow window of maintenance schedule are not easy to solve.

To solve these problems, the authors are developing a new floating wing turbine system. It is the Vertical Axis Wind Turbine (VAWT) mounted on a rotating cylindrical float (spar buoy). The shape is like a rotating fishing float equipped with VAWT blades. The spar buoy rotates with the vertical axis rotor. Power take-off from the rotor is by multiple roller units contacting on the cylindrical surface of the rotating float. The concept is called Floating Axis Wind Turbine (FAWT) because the rotor is floating with the buoyancy of the shaft.

The structural weight of FAWT will be lighter than those of floating HAWTs because of its smaller float size. VAWT rotor is not top-heavy and its allowable tilt angle (about 30 degree) is much larger than that of HAWT (about 3 degree). In addition, FAWT does not require large mechanical bearings since the heavy weight of vertical axis rotor is directly supported by sea water (or buoyancy).

To demonstrate the concept, the authors conducted a water tank test of 1/100 scale 5MW turbine model, model test of power take-off system and the preliminary structural analysis of FAWT rotor. The results show that the economic performance of FAWT will be competitive with the present bottom-fixed offshore wind turbines.

Proposal of Common floating station with Triangle connection and Rectangular link mechanism for Offshore wind farm with VAWT in deep sea and Evaluation of VAWT with Flip-up mechanism and Movable leading edge slat

Tatsuhiko Nagata and Yasuo Ueno

Individual

Abstract:

We have the responsibility to develop sustainable energy resources such as wind power for the benefit of future generations. Since the Tsunami disaster on March 11, 2011, people in northern Japan have experienced very difficult hardships. The accident at the Fukushima nuclear power plant has made it clear that nuclear power is very difficult to control and alternatives to both nuclear power and fossil fuels are essential. The prime candidates are renewable energy sources such as solar power and wind power. Seventy percent of the earth's total area is ocean, of which about 64% is deeper than 200 meters. These expansive ocean areas could be a major energy resource in future. If we can discover a better solution for offshore wind farms in the deep sea, we need not use nuclear energy. The Fukushima offshore wind power plant has introduced a horizontal axis wind turbine (HAWT) and actual operations have started. During the course of HAWT usage over time longer performance and stability have been demonstrated. However, is HAWT the right technology for off shore deep sea wind farms? Perhaps not. Most of the current onshore wind turbines are horizontal-axis. However, those systems have several problems such as unbalanced load around the rotating shaft and the need to yaw to face the direction of the wind. Floating structures with HAWT devices require big, heavy, expensive, and complex mechanisms to overcome these problems. Clearly another solution is required. A requirement for an alternate solution should be that the axis of rotation of the windmill and buoyant structures should share the same thing. Only vertical axis wind turbines (VAWT) could meet this requirement. Darius, Line Darius, and Line Darius with Flip-up Mechanism are examples of high speed VAWT. Development of this solution would require at least 10 years or more. The author, Nagata, has developed some VAWT designs with Flip-up Mechanisms and built prototypes in the past few years. Satisfactory results have been obtained. The weak point of VAWT is the low torque in low wind velocity. A VAWT design with a leading edge slat proposed by Mr. Ueno might be one of solution. The author made a prototype of a movable leading edge slat (MLES) last year. VAWT with MLES could generate 1.9 times more torque compared to VAWT without MLES at low wind velocity. The combination of MLES and VAWT with a flip up mechanism might be very useful for an off shore wind system. Additionally, the author made a small system with three floating towers combined into a Try Angle Connection and Flexible Rectangular Link Mechanism. This floating tower was tested on the water in a small tank with promising results. Additionally, good performance was achieved under several conditions at lake and river test sites. The author proposes the new concept of an offshore wind turbine system with self-stable VAWT with the flip-up mechanism and MLES and floating structure with flexible rectangular link mechanism and Triangle connection for deep sea locations. The author proposes to start the discussion for offshore wind systems with various kind of VAWT for the benefit of future generations at WWEC2016 in Tokyo.

Aerodynamic Design and Analysis of Offshore Wind Turbine Blades

Koji Fukami and Masaaki Shibata

Mitsubishi Heavy Industries, Ltd.

Abstract:

Against the backdrop of rising fuel prices and the introduction of tighter regulations for greenhouse gas emissions, the expectations for renewable energies have been growing all over the world. In Japan, this trend has become especially evident in the aftermath of the Great East Japan Earthquake in March 2011. Among a variety of renewable energy sources, wind power is one of the most widely installed around the world – in particular, offshore wind power has drawn growing interest in recent years owing to its applicability over vast sea area with stable and powerful wind condition. Especially in Japan, the concept of the floating offshore wind turbine will be more attractive because the country is surrounded by deep sea environment.

Since noise regulations for the offshore installations are less strict compared to the onshore case, it is possible to have a higher blade tip speed, which is expected to lead to an alleviation of aerodynamic moment load by use of more slender blades. In addition, an increase in the rotational speed allows us to reduce the design torque of the drivetrain, which will contribute to weight reductions of the rotational components. It should be noticed that higher tip speed would raise the erosion risk of the leading edge; however, this constraint could be relaxed with recently developed erosion-resistant coating agent. Major technical issues remaining at this point were the trade-offs of the load, weight and deflection with aerodynamic performance, which imposed on us the developments of more advanced technologies with regard to aerodynamics, blade structure, lightning protection system design, manufacturing of blades and optimization techniques that coordinate all these requirements.

This paper focuses on aerodynamic design and analysis of offshore wind turbine blades. Airfoils were among the countermeasures, which should provide higher structural integrity as well as improved aerodynamic performance. In the late 2000's, multi-megawatt onshore turbines with rotor diameters exceeding 100m became the mainstream of the onshore wind turbines with intensifying the demand for load and noise reduction. As a result, it was required for the airfoils to realize (1) high design lift coefficients and (2) lower noise characteristics. We have developed MHI-F airfoil series that have high design lift coefficients and low noise features as well as high performance (maximum lift-to-drag ratio). For the development of the offshore wind turbine blades, two more requirements were demanded: (3) higher section modulus for the weight reduction of the inner section and even also the tip section as well and (4) enhanced lift-to-drag ratio especially for the tip section to maintain the aerodynamic performance with higher tip speed, which might causes the greater drag derived loss due to the decreased inflow angle. While maintaining the advantages of the MHI-F airfoils, such as low noise and roughness resistant features, etc., we obtained higher strength (section modulus) as well as enhanced performance (maximum lift-to-drag ratio).

Passive cooling system for 5MW downwind turbine

Shigehisa Funabashi, Shingo Inamura and Yasushi Shigenaga

Hitachi, Ltd.

Abstract:

The expectation to renewable energy increases is still rising with environmental problems such as the global warming. Hereafter, offshore wind power is regarded as the main player of renewable energy and offshore wind turbine size is increasing to generate more electric power. Large offshore turbines are required high reliability because of severe environment in offshore.

Hitachi has developed the bottom-mounted offshore wind turbine (HTW5.0-126) which generates 5MW electricity with the rotor behind the nacelle (i.e. downwind-type). For this turbine, we have developed original passive cooling system to fit downwind-type turbine. The radiators located in upstream of the nacelle is benefit to get enough air flow rate without cooling fan, because wind speed at radiator located upstream from rotor, is not decreased. The utilization of natural wind enables to remove electric fan motors rotating in humid and salty air. It brings not only reduction of energy consumption and maintenance for electric fans, but also improvement of reliability of the cooling system.

At first, we designed the nacelle and radiator configuration to get enough air flow rate for a generator and gearbox cooling. As a result of many flow calculations, we could get distinctive nacelle design which have the radiators in front of the nacelle, and air outlet in the both side and the bottom of the nacelle. It looks like a mouse of whale shark.

In the prototype test of this turbine, we verified the performance of the passive cooling systems. The water temperatures at the exit of radiators were higher in low wind speed condition than high wind speed condition. It is characteristic trend as passive cooling system using natural wind, because this result means that high wind speed brings high cooling performance. Measured performance of this cooling system has good agreement with calculated result by simple heat balance model, and we could confirm that this system have enough performance to achieve target water temperature at the generator inlet.