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[Invited Speaker]

European R&D cooperation in wind energy

Peter Hauge Madsen

Head of Department of Wind Energy, The Technical University of Denmark

Abstract:

Cooperation on R&D in wind energy between research institutes and universities and alignment of the research in the individual member states with the European Union's framework programme, p.t. Horizon2020, is a key element of the EU SET-plan, which aims to overcome Europe's climate and energy challenges. In rder to provide strategic research leadership, coordination and alignment the major research organisations in Europe formed the European Energy Research Alliance (EERA) some years ago. The Joint Programme for Wind Energy (JPWind) was among the first 4 joint programmes and has now functioned for five years. In parallel the European Commission has supported the formation of Technology Platforms, which has been industry led and acted as a platform for discussions between industry and academia and joint priorization of R&D needs. In September 2016 the European Technology and Innovation Platform for Wind Energy (ETIPWind) presented its latest Strategic Research and Innovation Agenda with contributions from EERA JPWind. The presentation will focus on the organization and joint programming of European wind energy research in EERA JPWind, and present the strategic research recommendations of the industry and academia in ETIPWind.The presentation will conclude with some key results from the larger research initiatives of the EERA Joint Program for Wind Energy, namely the DTOC and the Innwind projects. The results demonstrate how cooperation in wind energy R&D can lead to design & analysis tools as well as innovations well above the limitations of the individual research groups.

3D analysis of a straight-bladed vertical axis wind turbine by panel method

Alisa Nakai, Takao Maeda, Yasunari Kamada, Junsuke Murata, Masayuki Yamamoto, Tatsuhiko Ogasawara, Kento Shimizu and Takuji Kasuya

Mie University

Abstract:

Vertical Axis Wind Turbines (VAWTs) have an axis of rotation which is normal to inflow wind. Because the power output of VAWTs independent of the direction of the wind, they don’t require any yaw mechanisms. In addition, straight-bladed vertical axis wind turbines which have uniform blades, without taper and without twist, suit mass-production because of the simple structure. Therefore, VAWTs have a possibility of lower manufacturing cost than that of Horizontal Axis Wind Turbines (HAWTs). Additionally, total gravity center of VAWTs are lower because generators of VAWTs can be placed near ground resulting in higher stability. It can be said that VAWTs have a potential of applying as urban-type wind turbines.

Even though much effort on research of VAWTs has been made, the understandings of effects of the complex flow fields aren’t enough to design low-cost and highly-efficient VAWTs.

Important factors which make the problem difficult are unsteadiness of relative inflow to blades and 3-dimensionality of flow filed. Magnitude and direction of relative inflow to the blades vary with azimuth angle. Especially in downstream half of the rotor, the blade pass through the flow field disturbed by upstream blades. It brings about periodic aerodynamic load fluctuation. Finite length blades generate tip vortices which form 3-dimensional induced velocity field around the rotor.

The purpose of this study is clarification of 3-dimensional effects on aerodynamic force fluctuation of straight-bladed VAWT rotor. For the purpose, panel method based on lifting line theory is used. In this method, rotor blades and wake are represented by vortex panels. Aerodynamic force on rotor blades are determined by Neumann condition at the blade surface considering the induced velocity from other rotor blades and wake calculated by Biot-Savart law. The method has advantages that it is capable of calculation for unsteady and 3-dimensional flow fields and the computational cost is lower than that of computational fluid dynamics (CFD).

In this study, aerodynamic performance and load fluctuation on straight-bladed VAWTs are calculated by the method. The calculation results are compared to wind experimental results observed in a wind tunnel. In the wind tunnel experiment, pressure distributions on rotor blade section at different span positions are measured.

The calculation results show qualitative agreement with the experimental results. Sectional aerodynamic force is largest at the middle of blade span and decreases with approach to the tips. This paper shows the effects of 3-dimesional flow field on aerodynamic force on straight-bladed VAWTs.

Evaluation of wind turbine wake simulation focusing on grid resolution

Keita Kimura[1], Yasutada Tanabe[2], Takashi Aoyama[1], Makoto Iida[1], Yuichi Matsuo[2] and Chuichi Arakawa[1]

[1]The University of Tokyo, [2]Japan Aerospace Exploration Agency(JAXA)

Abstract:

Numerical analysis is less expensive than an experimental setup and it readily provides field data such as velocity and vorticity. However, to simulate the entire structure of a wind turbine wake, a large number of grid points is needed. In this study, The influence of the grid resolution on wake characteristics is studied by changing the number of grid points of the wake region. Such information can be useful to reduce the costs of the CFD simulation of wind turbines.

In this paper, a CFD analysis is performed by using rFlow3D, which was developed by the Japanese Aerospace eXploration Agency (JAXA). Note that rFlow3D can handle moving overlapped structured grids and can accurately simulate rotating blades. In wake region, high-resolution grid is set to capture the complex wake structure such as tip vortices. By changing the resolutions of grid, the effects on wake characteristics such as velocity recovery and vorticity are investigated.

According to the results obtained by the CFD, values do not significantly change as for overall wake characteristics. Despite large changes in the grid resolution, velocity recovery and/or vortex breakdown process indicate similar tendency. On the other hand, the microscopic values such as the maximum vorticity and core radius of the tip vortices were found to be susceptible to changes in the grid resolution. As the grid resolution decreased, the vorticity decreased and the initial core radius increased. However, the vorticity decrement rate was the same for the medium and coarse grids. These results suggest that if a coarse grid does not capture several microscopic values, the overall advection process is reasonably simulated. That means grid resolution for wind turbine simulation can be classified according to the focusing scale. (For instance, a coarse level can simulate macroscopic advection of the vortices. Meanwhile, a fine level can capture the maximum and minimum values of vortices)

In the presentation, the results of additional cases will be shown. In addition, the relationship between the computational domain of high resolution grid and recovery process will be discussed.

Wind-powered Thermal Energy System (WTES), which employs direct thermal conversion and thermal energy storage

Toru Okazaki, Hiroshi Hasuike, Kenji Watanabe and Taro Kawamura

The Institute of Applied Energy

Abstract:

Wind-powered Thermal Energy System (WTES) is the novel simple idea to realize the economic base load power source. Present wind power is intermittent and cannot be operate without the back-up fossil fuel thermals. WTES is proposed to overcome this issue. The thermal energy is generated from the rotating energy directly at the top of the tower by the heat generator, which is very light and robust electric brake. The rest of the system is the same as the tower type concentrated solar power (CSP).

The advantages of WTES are: 1) economical direct drive system, 2) reliable heat transfer system, 3) very economical thermal energy storage, 4) very high capacity factor of transmission line, 5) dense deployment of wind towers in wind farm, 6) full-harvesting of the wind energy at the tower. The advantage No.1 is realized by the light and robust heat generator, which is the eddy current brake. No.2 & 3 are proved in CSPs. The energy storage cost by thermal condition is only 1/20 to 1/100 of the batteries. No.4, 5 and 6 are realized by the thermal storage. The power output has no direct connection with the wind condition. No.5 is also realized by the robust direct drive.

The disadvantage is the employment of inefficient thermal machine, of which efficiency is half of the batteries. This well-known fact blocked the study of WTES until recently. The quantitative research from the viewpoint of total electric power system reveals that the economic efficiency of WTES is much better than that of the conventional wind power stabilized by the both back-up thermals and batteries. This quantitative research of energy cost is reported in this study.

[Invited Speaker]

Advanced aerodynamic rotor control options: Flaps, Plasma's and modern stall control

Gerard J.W. van Bussel and Ricardo Pereira

Wind Energy Group, Faculty of Aerospace Engineering, TU Delft

Abstract:

The paper presents the result of a study on an alternative horizontal axis wind turbine rotor concept in which modern active stall control (ASC) is adopted.

In this concept the power control of the wind turbine is achieved in a combination of rotor speed control and active flow control actuators. These two control modes are used to fine tune the aerodynamic blade loads across the complete operational envelope.

In the operational range from cut-in to close to the nominal wind speed, the wind turbine is operating just as an ordinary modern pitch controlled rotor. But above the nominal speed, the rotor speed is kept constant and active flow devices are applied to control loads around rated power and above.

It will be shown that, out of several active flow control devices such as trailing edge jets, smart trailing edge flaps and plasma actuators, on the plasma actuators applied on selected locations on the suction side of the rotor blade, can provide sufficient control authority to control the loads in a satisfying fashion.

Out of the several plasma actuation possibilities the Alternating Current Dielectric Barrier Discharge (AC-DBD) plasma actuator, characterised by a.o. the absence of moving parts, negligible mass and virtually unlimited bandwidth of actuation came out as the best implementation.

An extensive study was performed at TU Delft on the performance of such actuators. This is not part of the current presentation, but its results are used to design a series of AC-DBD actuated airfoils for implementation into ASC rotor blades witch will be presented.

A final rotor planform design for a 5MW rotor will be presented as well and it includes the planform geometry design, rated rotational speed, spanwise laminate skin thickness as well as the dedicated AC-DBD plasma actuated airfoils ("WAP" airfoils) with the actuation scheduling,

Results show that, compared to variable-pitch rotor blades, the ASC planform displays increased chord at inboard stations with decreased twist angle towards the tip, resulting in increased AOA. Actuation is employed to trim the loads across the operational wind speed envelope and hence results in a significant reduction of load overshoots.

Aerodynamic Loads of Horizontal Axis Wind Turbines in Realistic Operational Conditions and Loads Mitigation Using Individual Pitch Controls

Yasutada Tanabe[1], Takashi Aoyama[1], Harutaka Oe[2], Makoto Yamamoto[2], Makoto Iida[3] and Chuichi Arakawa[3]

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Abstract:

Aerodynamic load of horizontal axis wind turbine (HAWT) operated in realistic complex conditions such as yawed wind and atmospheric boundary layer (ABL) wind profile are studied. Individual pitch control (IPC) technique is applied for the load mitigation especially for the HAWT operated in ABL inflows. Larger wind turbines are under development to pursue greater efficiency. More challenges exist in the design of the larger wind turbines where higher reliability and endurability are required especially in Japan where severe gusts and typhoons frequently visit. Understanding of the aerodynamic loads in more realistic operational conditions is the start point. A CFD code, rFlow3D, developed in JAXA especially for the applications to rotorcraft is extended for simulating the HAWTs operations. It was validated with the NREL Phase VI and MEXICO wind turbine experimental databases. It is found that in yawed wind, the variations of the aerodynamic loads increases with the increase of yaw angle. The load variations in the ABL inflow condition are significantly high. An individual pitch control system to reduce the yawing and tilting moments of the wind turbine in ABL is constructed and a trim routine is numerically simulated and the effectiveness is validated based on a three-bladed and a two-bladed horizontal axis wind turbine. It is found that the averages of yawing and tilting moment on the rotor hub can be reduced nearly to zero through the 1/rev cyclic controls. Furthermore, the fluctuations of the moments on the hub of a two-bladed wind turbine can be significantly reduced simultaneously through the 1/rev cyclic control. The oscillations of the flapwise bending moments on blade root can be remarkably reduced although the averages are not influenced while the influence of IPC on the power generation is minimal.

Detailed wind inflow measurements using a nine-beam nacelle lidar

Hirokazu Kawabata, Yoshihiro Kikushima and Tetsuya Kogaki

Advanced industrial science and technology

Abstract:

This study reports on wind inflow measurements performed using a nine-beam nacelle lidar. Various nacelle lidar systems have been used for the measurements of wind inflow to realize high-performance wind tur-bines. The measurement of a two-beam nacelle lidar used as a simple measurement system has been compared with those of a nacelle anemometer and a met-mast. The 10-min-averaged data obtained from the two-beam nacelle lidar have good measurement accuracy, but the lidar is unable to measure wind shear. Monitoring of wind inflow for multi-megawatt wind turbines requires an advanced lidar system that can measure wind shear. Further, there is a lack of observation reports on measurements using the two-beam nacelle lidar under strong turbulence conditions. In this study, the authors evaluated the measurement characteristics of a nine-beam nacelle lidar installed on a 300-kW wind turbine. This nacelle lidar could measure radial wind speeds in nine directions; further, horizontal wind speeds were calculated using a three-beam system. The use of three beams led to a considerably higher availability of the lidar in comparison to the availability when using two beams. This lidar also could measure wind speed uniformity in a transverse direction by using three beams. The measurements of this study revealed that 10-min-averaged data could confirm wind uniformity, but instantaneous data could not confirm wind uniformity under a strong turbulence condition. To discriminate the lidar measurement data in terms of their quality, some filtering indexes for these data were proposed. Continuous and reliable monitoring of wind shear could be achieved by filtering the measured data. The nine-beam nacelle lidar was also used for the detection of strong turbulence. Because of the high data availability, the lidar could measure strong turbulence information for feedforward control.