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120	PS-G-4	The Development of An Innovative Small Wind Power Generator	Dr. Ming Chun Hsieh	Dept. Electronic Engineering, Kun Shan University
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123	PS-I-2	Concealed Multi-Rotor Ducted Wind Turbine	Mr. Allen Kwok Fai Chan	Independent Inventor
128	PS-I-3	Gravity Induced In-plane Self-excitation of 2-bladed Flexible Rotor	Prof. Shigeo Yoshida	Kyushu University/Research Institute for Applied Mechnicals
129	PS-I-4	Inflow Coherence Effects on Multi-Rotor Wind Turbine System	Prof. Shigeo Yoshida	Kyushu University/Research Institute for Applied Mechnicals
130	PS-I-5	Influences of Rotor Thrust on Tower Shadow Effects of Downwind Turbines	Prof. Shigeo Yoshida	Kyushu University/Research Institute for Applied Mechnicals
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A Tethered Airborne Wind Turbine System

Allen Kwok Fai Chan

Independant Inventor

Abstract:

A tethered airborne wind turbine system includes a train of pilot buoyant parafoils, a power generating parafoil with built-in turbines; a nacelle being sandwiched by two rotating blimps and suspended beneath the said power generating parafoil by composite cable, and a transmission shaft coupled to a train of reversed windsock propellers annexing thereto the rear. The train of pilot buoyant parafoils, each being interconnected from top-to-bottom by composite cable, will provide buoyancy to sustain the said airborne wind turbine system aloft. The nacelle ,with its two blimps being driven to rotate as wind passing for power generation, is suspended beneath the power generator parafoil via composite cable. The said train of reversed windsock propellers with vanes on the surface serves as a directional tail, which is caused to rotate in strong wind, delivers the torque via a transmission shaft to the rear of the nacelle to drive the built-in generator for power generation. The power generated may be processed in the nacelle for delivery to the ground via composite cable and/or via wireless power transmission when technology permits in the future. The system can be deployed as a wind farm on the ground by means of an array of trains of the reversed windsock propellers being hung onto a steel grid system supported by steel towers wherein, the trains of reversed windsock propellers drive their respective outboard generators to generate electricity as wind passes by.

Unsteady wake analysis of horizontal axis wind turbine rotors with reduced calculation load

Yutaka Hasegawa[1], Kazuki Kubota[1], Shinichi Oda[1], Tatuso Ushijima[1] and Hiroki Suzuki[2]

[1]Nagoya Institute of Technology, [2]Yamaguchi University

Abstract:

The operational control of the horizontal axis wind turbine, such as blade pitch control and/or speed control of the turbine rotor, is one of the useful methods to reduce the temporal variation of wind turbine output. For the optimization of the control method, the response of turbine performance has to be clarified with respect to the changes in operational condition.

We have examined the effects of wake inertia on the aerodynamic response of turbine performance when the blade pitch is temporally varied under stationary inflow condition by using numerical calculation. The change in the operational condition of turbine rotors brings about the temporal variation of the blade load distribution, which alters the shed vortices and trailing vortices from the blades. Then vortex wake structure of the rotor gradually changes with time in the downstream. The dynamically varying wake induces unsteady velocity field around the rotor blade, which in turn influences the distribution of the blade load. This mutual interaction between the unsteady distribution of the blade load and the dynamically varying wake is called wake inertia effects or dynamic inflow effects.

For the calculation of aerodynamic load on the rotor blade, an inviscid aerodynamic model based on the vortex lattice method with an unsteady wake model is adopted, which is capable of calculating the unsteady aerodynamic loads. For the wake analysis of the horizontal axis wind turbine rotors, there are two methods; the fixed wake model and the free wake model. The former is a model with prescribed structure of wake vortices, and the latter calculates the wake vortex structure at every time step by moving all vortices at respective local speeds. Since the computation load for free wake model is large, several methods to reduce the calculation load have been proposed. For example, the effect of wake is limited only the specified area (hybrid wake model), and the wake structure is simplified into the contour of the wake (contour dynamics).

In the present study, we have constructed a hybrid wake model that combines the free wake model and the fixed wake model. The validity of our wake model about the calculation accuracy has been examined by comparing the results with those by the free wake model, for the case of the steady operational cases, and the pitch control cases with stationary inflow conditions. The comparison shows good agreement and the validity of the hybrid wake model has been confirmed especially for the pitch control cases.

Concerning about the calculation load reduction, the hybrid wake model shows fairly good performance. The calculation time required for the analysis of 100 revolutions of the rotor could be reduced by the hybrid wake model as much as 98% compared to the free wake model. Those long term calculations are necessary for the fatigue load calculations. Therefore the aerodynamic load calculation code with the hybrid wake model is also useful even for the fatigue load calculation.

Theoretical-Numerical Analyze of the Performance of a Vertical Axis Wind Turbine with Movable Blades

Willmari Dayana Suarez and Ramiro Gustavo Ramirez

UNIVERSIDADE FEDERAL DE ITAJUBA - UNIFEI

Abstract:

Wind Power as a source of energy generation free of greenhouse effects, has reached such a degree of technological maturity and economic competitiveness in the last 25 years that have made it the most attractive option for new power generation facilities; from own resources, it is being considered into the diversify energetic structure of practically every country in the world. The purpose of this work is to analyze the performance of a vertical axis wind turbine which depends only of the acting area of its blades, resulting in a more efficiently use of the wind power. The wind turbine was designed to reduce the negative torque produced by the blades when at the opposite direction of the wind; this is achieved by the use of movable blades that remain in a horizontal position. Considering its high efficiency at low speeds, simple construction and technology, this kind of vertical wind turbine can have multiple applications; to do mechanical work and for power generation.

The VAT (Vertical Axis Turbine) consists of two fixed rotors on a vertical axis, each rotor consists of two normal axes that have four blades which are formed by two rectangular blades that open and close by the action of the wind. The VAT catches the wind in any direction without the required of additional equipment such as sensors, windsock, motors, etc., to redirect it towards the wind direction.

The objective of this paper is to get an estimate of the Vertical Axis Turbine performance, through a theoretical-numerical approach which will help to validate later analysis and improvements of the turbine design.

With the purpose to get a more realistic approach of the Vertical Axis Turbine theoretical performance, the variation of the mean drag coefficient (Cd) was

determined using CFD (Computational Fluid Dynamics) considering the variation in a steady-state regime of the drag within different openings of the blades for different speeds.

Results of the power coefficient behavior from the theoretical, numerical and experimental analysis where the variations of the power coefficient as function of the wind speed follow the same trend are reported. A further analysis of those result shows that the maximum power coefficient analytically obtained is 38%, and the operating speed range of the turbine at higher yield is between 3 to 7 m/s, making this type of wind turbine very interesting in low wind speed regions.

Taking into consideration the level of complexity of the operation of this type of turbines for a dynamic analysis using computational fluid mechanics, mainly due to the number of degrees of freedom of the system; an estimate of the performance of the turbine by means of an analytical analysis managing to predict accurately the performance of energy extraction of a system with mobile blades; is a significant step forward into a more sophisticated design, helping to have the best setting when carrying out more advance and costly studies.

Building Integrated Wind Turbine

Allen Kwok Fai Chan

Independant Inventor

Abstract:

The present application is directed to a building integrated wind turbine comprising: a generator mounted on a chassis and coupled to a plurality of tangential fan wheels, all being housed in a shrouded cover with two long openings for the said fan wheels one at the front intake and the other at the rear discharge. Wind-directing panels extend outwardly from the two said fan openings to form the front intake and the rear discharge which, together with the vast building area, form augment thereby wind is pressurized in the windward side at the front intake and forced to diffuse through the wind turbine at a higher speed. As soon as the wind passes through the fan wheels and enters into the discharge region at the rear, a negative pressurized zone is instantly developed to become partial vacuum due to rapid expansion of air thereby helping draw in more air from the front at further accelerated speed; the acceleration process reciprocates until a threshold incoming wind speed has been reached ultimately to enhance wind energy exponentially. The building integrated wind turbine performs more silent than a wall-hung bedroom AC fan unit as it operates on a reverse operation thereby permitting its direct installation on rooftop and external walls of building since the transmission of vibration and noises to the building premises is negligible. The building integrated wind turbine is recommended to install in synergy with a photo voltaic system to share the common cost of the control system for best economical operation.

An innovative wind / water turbine with circular cylinder propeller driven by longitudinal vortex

Tsutomu Takahashi, Yumiko Yoshitake, Kasumi Sakamoto and Withun Hemsuwan

Nagaoka University of Technology

Abstract:

A newly developed innovative wind / water turbine mechanism that is driven by longitudinal vortex is introduced. The shape of this turbine is simple, that is, the blades of a conventional propeller type windmill with a horizontal rotation axis are replaced to the simple circular cylinders and a ring shaped plate is placed in the wake region. This very simple circular cylinder blade propeller turbine can rotate by both air and water flow and exhibits completely different property from the conventional windmill. Each blade of this circular cylinder propeller is fixed on the horizontal rotary axis, not spinning around their center axis. Namely, Magnus effect is not a driving force of this turbine. The circular cylinder blade is a symmetrical shape and then it does not generate the steady left force from the flow in a resting state. However, the longitudinal vortex sheds periodically from the gap between the cylinder blade and the ring plate and it makes rotational fluctuation around the horizontal axis. Once the propeller starts to rotate a certain direction, the longitudinal vortex appears stably behind the cylinder and the steady lift force is generated. It can rotate to the CW or CCW direction and the rotation direction is decided by the initial rotation direction. The angular velocity of the propeller achieves a certain value in the equilibrium state and the equilibrium angular velocity increases linearly with increasing the main flow velocity. The relative incident angle defined by the main flow velocity and circumferential velocity keeps a constant value. The angular velocity caused by this turbine is lower compared with the conventional propeller turbines, but it can generate strong torque. The trial test turbine exhibits smaller value of the power coefficient, less than 0.04, but the torque coefficient achieves 0.35. Therefore, this turbine generates high torque at low angular velocity, such as the pressure driven turbines. The power and torque features can be brushed up by finding an optimum shape.

The gap between the propeller and the ring plate is an important factor of this turbine. The steady lift force increases with decreasing the gap, but there is a critical gap to generate rotation. The propeller does not rotate when the gap is smaller than the critical gap. It is one of the advantageous features that the rotation of this turbine can easily control by change the gap. The diameter of the circular cylinder blade and the width of the ring plate are also an important geometrical factor for the performance.

This new turbine is the simple structure, toughness and high torque feature. Therefore, it has a great possibility to use as a wind turbine to generate electricity in the polar region or strong wind area, but also it can apply for wider purposes. For example, the shape of the propeller is so simple that it is easily manufactured by ceramics or some special hard metal. Then, we can make a turbine with high corrosion resistance and temperature resistance. We can also manufacture a micro-size turbine easier.

Experimental studies on load suppression of wind turbine by Lidar associated control

Atsushi Sawaki, Takao Maeda, Yasunari Kamada, Junsuke Murata and Kouta Morimoto

Mie University

Abstract:

As a renewable energy, the wind power has been developed all over the world in recent years because of its large-scale deployment. Nevertheless, due to a large turbulence intensity and a lower annual mean wind velocity, it is technologically hard to achieve a high-energy efficiency from onshore wind resources. Therefore, more and more researchers are focusing on the development of Floating Offshore Wind Turbine (FOWT), which offers the prospect of utilizing the vast amount of high quality wind resources in water depths.

FOWT will receive large oscillations such as aerodynamic force of wind and hydrodynamic force of wave. These external forces may change the wind turbine attitude. It may decrease its output performance and increase the failure of turbine system. Thence, in the design process of the FOWT, it is very important to investigate the wind turbine behaviors. The largest moment acting on the FOWT is caused by the rotor thrust force that can control by changing blade pitch angle. In this study, the possibility of the thrust control with Lidar measurements is evaluated. The pitch angle change can cause the thrust change, however the wind speed variation also change the thrust. If the wind speed information is collected before entering wind turbine rotor, the wind turbine can set the desired thrust to stabilize the wind turbine altitude. To detect inflow wind speed, the test wind turbine has Lidar system. The thrust force on rotor is directly measured by load cell which is installed between the tower top and the nacelle. The test wind turbine is up-wind type HAWT with three-bladed and the generator capacity is 37kW. The tower hub height is 13.4m and the rotor diameter is 10.0 m. The control system includes both variable speed and variable pith system.

In field experiments, the observed inflow velocity is inserted to the wind turbine control system. The control system can set the rotor torque and the pitch angle. The performances of Lidar associated control system of wind turbine are discussed under the natural wind. Furthermore the wind arrival time from the wind velocity observation position to the wind turbine rotor surface are experimentally investigated. Therefore, it can predict the thrust force applied to the wind turbine. In this research, the system performance is evaluated at the viewpoint of the thrust fluctuations. The results of this analysis will help the fundamental design of suppressing undesired turbine's load for FOWT.

Study on 3D effect on aerodynamic performance of a straight-bladed Vertical Axis Wind Turbine by CFD simulations

Kento Shimizu, Takao Maeda, Yasunari Kamada, Junsuke Murata, Qing'an Li, Takuji Kasuya and Alisa Nakai

Mie University

Abstract:

The application of a small straight-bladed Vertical Axis Wind Turbine (VAWT) has been increasingly contributing to the energy supply because of its power generation system and unnecessity of yaw mechanism. Therefore, more and more researchers are focusing on the development of a straight-bladed VAWT to be used in the city.

It is well known that the VAWT have an inherently unsteady aerodynamic behavior during rotation, because of the large fluctuation of the resultant wind velocity and angle of attack to blade, especially at low tip speed ratios. With the increase of angle of attack, an increased adverse pressure is developed, thus causing the flow separation and reattachment at the rotor surface. Additionally, VAWT have 3 -dimensional flow. There are two reasons why VAWT have it. First, wing-tip vortex causes induced drag because rotor blades of VAWT is a finite width. Second, rotor thrust causes the flow of escaping to the left and right in a horizontal plane so as to bypass the rotor plane flow to escape up and down in the same way is also to produce. Thence, it is a serious challenge to investigate VAWT aerodynamic forces and flow fields which are notoriously difficult to predict, especially the airflow around the blade surface.

The objective of this paper is to illustrate the 3D effect on aerodynamic performance of VAWT by CFD simulations.

For CFD simulations, a three-dimensional computational domain is designed to simulate the pressure distribution acting on the blade surface and wind velocity around the rotor blade by numerical analysis using software FLUENT. To avoid the blockage effects and disturbances of outer boundaries, the computational domains are extended sufficiently as follows:

For wind tunnel experiments, in this study, the radius of VAWT is 1.0 m and the number of blade is two. The tested airfoil is NACA0021 with a span length of 1.2m in an inner diameter of wind tunnel of 3.6 m. The pressures on the rotor blade surface are directly measured at the center of blade span through the use of a multi-port pressure scanner. Moreover, a six-component balance can measure the forces and moments applied to the entire wind turbine. The effects of the tip speed ratio on the flow field and power performance of the VAWT are investigated.

The present paper provides a better understanding of the aerodynamic performance and flow filed of straight-bladed VAWT, according to comparing the results from wind tunnel experiments CFD calculations in three-dimensional analysis. Additionally, we examine validation of the model by comparing results from wind tunnel experiments and CFD.

Key Words : Straight-bladed Vertical Axis Wind Turbine, CFD simulations, 3D effect, Wind tunnel experiments, aerodynamic performance.

Multi-Rotor Ducted Wind Turbine

Allen Kwok Fai Chan

Independent Inventor

Abstract:

The present application is directed to a multi-rotor ducted wind turbine system comprising: a plurality of high speed ducted wind turbines each moveably mounted onto the underside of the rotor blade of a horizontal axis wind turbine (HAWT) in the manner that the axle of the ducted wind turbine and the axis of the respective rotor blade carrying the ducted wind turbine are perpendicular to each other as if a jet engine being carried under the wing of a plane. The ducted wind turbines are symmetrically mounted under the respective rotor blades each traveling at a speed of $2\pi R$ times the r.p.m. of the rotor blades, 'R' being the variable distance of the ducted wind turbine from the axle of the rotor blades such that controllable high speed wind in couple tenths meter per second can drive the ducted wind turbine to run in couple thousands r.p.m. to generate electricity directly thereby elimination of gearbox and bulk generator in the nacelle will be achievable. As the rotor blades rotate, multiple stages of negative pressurized zones can be developed at various zones inside the shrouded duct region for purpose to draw in more intake wind from the front to achieve an exponential increase in the wind energy. As such, drastic saving in the initial investment and subsequent operation costs can be achieved since a gearbox dominates at least 13% of the total set up cost for a wind turbine whilst gearbox replacement has to be implemented every 5 years in accordance with the American insurance policy for wind turbines.

Wind tunnel study on the surface flow characteristics of a rotating blade of a horizontal axis wind turbine in three-dimensional analysis

Noriaki Sugimoto, Yasunari Kamada, Takao Maeda, Junsuke Murata and Shunpei Ito

Mie University

Abstract:

It is well known that aerodynamic forces of Horizontal Axis Wind Turbine (HAWT) strongly depend on a flow field on blade surface. A surface flow on a rotating blade can affect a sectional aerodynamic performance. In a development of HAWT, an optimal design of rotor blade is usually based on a blade element momentum theory, which does not take into account a radial velocity component acting on an aerodynamics force. However, a flow on the rotor blade surface includes a radial velocity during rotation. Furthermore, tangential components of relative velocity to blade sections are different at each radial position, resulting in different flow field. At the vicinity of blade surface, a boundary layer is generated and boundary layer transition and separation occur during a rotation. Therefore, the surface flow on the rotating blade becomes an extremely complex three-dimensional flow. It is a serious challenge to clarify the flow field characteristics at the vicinity of blade surface during rotor rotation.

In order to obtain a high efficient wind turbine, this research attempts to find out rotational effects on flow field at the vicinity of the wind turbine blade surface. A wind tunnel experiments are carried out at an open test section of a circular type wind tunnel in Mie University. The wind tunnel has an outlet diameter of 3.6 m with an air corrector size of 4.0 m × 4.0 m and the main test section has a longitudinal length of 4.5 m. A test wind turbine used in the experiment has a three-bladed rotor with a radius of 0.8 m. In this study, a free stream wind velocity is set on 8.0 m/s and pitch angles of rotor blades are 0°. Measurements are conducted at a tip speed ratio of 6.0, which corresponds to the optimal condition with maximum power coefficient of 0.42.

In the experiment, the wind velocity fields around blade surface are measured by a Laser Doppler Velocimetry (LDV) system. The three-dimensional LDV is operated with three argon ion lasers, with 514.5nm, 488.0nm and 476.5nm wavelength. The LDV system can measure the velocity fields with high accuracy.

In the study, the rotational effects on blade surface flow are discussed based on the radial component measured by the LDV system in the wind tunnel experiment. As a result, it is clarified that the rotational effects appear obviously on an inboard of the blade. Moreover, an increasing velocity region of the surface flow is generated in the near of a leading edge.

Effect of plasma actuator on the flow field characteristic of a Horizontal Axis Wind Turbine in wind tunnel experiments

Atsushi Fujiwara[1], Yasunari Kamada[1], Takao Maeda[1], Junsuke Murata[1] and Motofumi Tanaka[2]

[1]Mie University, [2]TOSHIBA Corporation

Abstract:

In Japan, natural wind has a strong turbulence intensity that causes dynamic stall of wind turbines due to the complicated terrain. This phenomenon can result in major changes of dynamic blade loads and lower power coefficient, because it involves a series of fluid flow attachments, separations and reattachments that occurred on the airfoil surface. It is possible to suppress flow separation from the blade with the plasma actuator technology. However, the effect of plasma actuator on the flow field around the wind turbine has not been clarified. Therefore, the objective of this study is to investigate the flow field characteristics when the plasma actuator is utilized in wind tunnel experiments.

In this study, the large wind tunnel is used for the experiment, which is an open test section of a circular type with the inner diameter of 3.6 m. The main test section has a development length of 6.2 m and the air corrector size is 4.0 m × 4.0 m. The deviation of flow uniformity is about 1.2% and the measured turbulence intensity is less than 0.5% at the inlet of the test section, when the free stream wind velocity is set at 8.0 m/s. The test wind turbine is a three-bladed upwind rotor Horizontal Axis Wind Turbine (HAWT). The diameter of this wind turbine is 1.6 m and the Avistar airfoil is applied.

To obtain different turbulence intensity patterns in the wind tunnel, a dynamic turbulence grid are used to generate the turbulence flow. This device can generate turbulence flow by reversing the movement of the rotating shaft which is attached by some stirring vanes. These stirring vanes are assembled in a grid of 0.13 m, the maximum value of blockage rate is up to 0.73 and the minimum value is about 0.19. In this experiment, the turbulence intensity is obtained up to 10.6% by the turbulence grid. The wind velocity around the HAWT model flow field is measured by an ultrasonic vane anemometer.

The power performance of the wind turbine is compared with and without the plasma actuator. From the results of basic performance, wind velocities around the flow field are observed at the low tip speed ratio and optimal tip speed ratio, when the plasma actuator is exploited and is not exploited. As a result, the power coefficient in low tip speed region is improved by plasma actuator. The tangential velocity component in the wake of rotor is also increased by the plasma actuator. It means this study provides a better understanding of the effect of plasma actuator on the flow field characteristic of the HAWT during rotation.

Wind Power Simulation and Analysis Incorporating Highly-Resolved Weather Prediction and Measurement Data of Japan

Fredrik Raak[1], Yoshihiko Susuki[2], Kazuhisa Tsuboki[3], Masaya Kato[3], Shinya Eguchi[4] and Takashi Hikihara[1]

[1]Kyoto University, [2]Osaka Prefecture University, [3]Nagoya University, [4]Wind Power Engineering Co.Ltd

Abstract:

In this presentation we discuss ongoing research on wind power analysis in Japan incorporating highly-resolved weather prediction data from the Cloud Resolving Storm Simulator (CReSS). There are mainly two objectives of this research. First, we aspire to clarify the usefulness of this type of weather simulation data for wind power analysis. Second, Japan is potentially facing a large-expansion of off and onshore wind power in the future, thus it becomes important to understand its potential implications and characteristics, which we attempt to address here.

The data obtained from the CReSS model consist of detailed data with 200 m spatial resolution and sampling time of 2 s, for two locations in Japan, and more coarse data of whole Japan with 2 km spatial resolution and sampling time of 1 h. A basic simulation environment for dynamic simulation of wind farms connected to power grids was first set up and initial simulations of wind farms incorporating the CReSS data were conducted.

In addition to the simulated weather data, real measured data of turbines from a wind farm in Japan were also incorporated. Utilizing this data, wind turbine characteristics of the real turbine were derived and included in a dynamic model. A statistical evaluation was then conducted to verify the dynamic model. The results indicated a good agreement between the dynamic model and reality in terms of capturing the fluctuations in the short term, in comparison with standard power curves. Currently, wind farm simulations including detailed weather prediction data are compared with measured wind farm outputs, and an evaluation is conducted to determine the usefulness and correctness of predicting the detailed wind farm output by our simulation systems.

Finally, an analysis of wind power smoothing in Japan is conducted. In a system with large penetration of electric power from intermittent energy sources such as wind, it is important to distribute the generation over a large geographical area, and allow for power exchange between different areas, to more easily smoothen the power production and utilize its full capacity. It thus becomes important to understand and describe the coherence of power generation at different locations when planning a suitable distribution of renewable power generation. To this end, more coarse CReSS data of whole Japan are used in addition to the detailed data, and a new smoothing measure based on the so-called Koopman Mode Decomposition (KMD) is described and proposed. It is shown how improvements in smoothing of wind power depending on the distribution of generation are captured by the proposed measure, and comparisons are made with a conventional measure of wind power smoothing.

Taut Mooring Method at Shallow Water for Floating Windmill

Katsunori Nakano

IDEOL

Abstract:

Taut mooring methods are usually adopted in case of deep water for developments of resources but because of a new super flexible mooring material and necessity of reducing occupancy areas, adoption at shallow water for floating windmills are reconsidered.

Further this conceptual method may result in new simple integrated unified anchors with more economical transportation and installation methods which can be claimed as more economical TCOs than those of some bottom-mounted methods. In case of catenary mooring systems, loose ends of cables are far apart then occupancy areas are rather large bothering fishery operator's works or passings of marine vessels. On the other hand, new conceptual taut mooring method can reduce occupancy areas down to less than one third and total scope length of mooring cables can be less than one fifth.

Model Predictive Control for Reducing Power Output Fluctuations and Platform Motions in a Floating Offshore Wind Turbine-Generator System

Tetsuya Wakui, Daisuke Miyanaga, Motoki Yoshimura and Ryohei Yokoyama

Osaka Prefecture University

Abstract:

Floating offshore wind turbine-generator systems are expected to operate in areas that have very deep waters. The stability of the power output and the platform motion must be simultaneously established in the operation of these systems at high wind speeds because they have a trade-off relationship induced by the blade pitch manipulation for the power/speed control. One effective approach is to develop a novel control strategy because the increase in the initial cost due to its implementation is slight as compared to development of a high-damping platform structure. Modern control theory-based approaches as well as classic feedback control-based approaches have already been reported in previous studies. However, employing a model control predictive approach is a minority, in which the control behaviors can be optimized based on the prediction of the future operating behaviors.

The present study develops a model predictive control approach for reducing both the power output fluctuation and platform motion in floating offshore wind turbine-generator systems. In the previous studies regarding model predictive control, future wind speed variations were predicted, while future wave height variation were regarded as disturbance or deterministic. In the present study, wave height variations as well as wind speed variations are predicted by using Kalman filters. The development is conducted through a numerical analysis of a 5-MW spar-type floating offshore wind turbine-generator system using the aeroelastic simulation model (FAST), MATLAB, measured high wind speed data, and simulated data of irregular wave height.

The controlled variables in the developed model predictive controller are the rotor speed and platform pitching velocity. The manipulated variables are the collective blade pitch and generator torque. The dynamic characteristics of the floating offshore wind turbine-generator system, which are constraints in the optimization problem to determine the manipulated variables, are expressed by using a multiple-input and multiple-output model linearized at an operating point. The manipulated variables during a given control horizon are determined so that the objective function, expressing the error of the control variables to their set points and the variations in the manipulated variables during the given prediction horizon, is minimized. The variations in the wind speed and wave height during the prediction horizon are predicted by using Kalman filters. The formulated optimization problem results in a quadratic programming one, which is solved by using MATLAB.

The operating simulation under high wind speeds and irregular waves reveals that the model predictive control provides the small variations in the rotor speed and platform pitch as compared with the gain-scheduled feedback control of the rotor speed developed by NREL and the multiple feedback control of the generator power and platform pitching velocity developed by the authors of the present study. This is because the model predictive control can manipulate the blade pitch and generator torque before the controlled variables, of which the dynamic responses are affected by large moments of inertia of the rotor and spar-type platform, are varied. Therefore, the developed model predictive control approach greatly contributes to the stabilization of both the power output and platform motion.

The validation of the motion performance of the advanced spar type floater

Yoshimoto Haruki

Japan Marine United Corporation

Abstract:

This paper describes about the validation of the performance of advanced spar type floater. As a conclusion, we make sure that the floater has designed motion and mooring performance by the observation data.

We had already constructed and installed an electric substation floater at off the coast of Fukushima. The purpose of the floater is to transform and transmit the electricity generated in Fukushima Offshore Floating Wind Farm. The wind farm was constructed in the demonstrational national project, “Fukushima Experimental Offshore Floating Wind Farm Project”, and consists of three types wind turbine floaters. The wind farm’s total amount of rating capacity is 14 MW.

The structure of the substation floater is “Advanced Spar Type”. Advanced spar is the newly developed structure and enables to suppress the motion of the float nevertheless it retains the characteristic stability that an existing spar had. And, it needs smaller area for construction than semi-submersible or the other type. The substation floater is the first application of the advanced spar and the performance of the advanced spar has not been confirmed yet at the project scale.

For the validation of the floater’s performance, we had installed many observation instruments on the substation floater (i.e. Anemometer, temperature sensor, GPS and more…). Especially to observation of the performance concerned with naval architect, we installed wave meter and some motion sensors.

The validation is conducted by the comparison of equivalent calculated and observation data at some typical terms. As a result we confirmed that the floater has the sufficient low motion performance as designed.

Moving and ReInstallation of Hybrid Spar Type Floating Offshore Wind Turbine

Iku Sato[1] and Tomoaki Utsunomiya[2]

[1]TODA CORPORATION, [2]Kyushu University

Abstract:

Floating offshore wind turbine demonstration project of ministry of the environment government of japan ware finished FY 2015.

April 1st ,2015 the floating offshore wind turbine ""HAENKAZE"" was put into practical use with 2MW.

Before finishing the project, Haenkaze removed from Kabashima and moved to the site near by Fukuejima.

To report the followings：

1) process of removing
2) survey and checking of mooring chain
3) Status update of operation

A Comparison of different LiDAR Systems in measuring Wind Characteristics at Complex Terrain Sites

Nobutoshi Nishio[1], Satoshi Nakashima[2], Hiroaki Fujio[3] and Makoto Iida[3]

[1]The University of Tokyo Department of Advanced Interdisciplinary Studies, [2]The University of Tokyo Department of Mechanical Engineering
[3]The University of Tokyo Research Center for Advanced Science and Technology

Abstract:

Wind turbines are often constructed in mountainous region in Japan, because mountainous region is account for more than 70 percent of land in Japan. In complex terrains, wind characteristics depend heavily on wind direction with strong locality. Especially the vertical wind profiles are complicated in the complex terrain. So, it is necessary to measure the wide-ranging wind conditions from a low altitude to a high altitude. However, wide-ranging wind measurements are difficult for conventional equipment such as meteorological mast. Remote sensing devices including Light Detection and Ranging (LiDAR) offers a state-of-the-art approach to the measurement of wind conditions. LiDAR technology offers the additional advantage of being deployable at hub height. Although LiDAR are counted on for wind measurements in complex terrain, measurements and analysis cases of mountainous ridge which is installed wind turbines are very small.

In this paper, we investigated the effects of terrain configurations on wind speed by wind measurements using different LiDARs in mountainous terrain. And we also investigated LiDAR measurements validity by comparison among the coefficient of correlation (R) for the 10-min averaged wind speed from three LiDARs (ZephIR, SpiDAR and Galion) that have different wind measurements mechanism. ZephIR is manufactured by ZephIR Lidar. The wind speed of this device is calculated from 50 radial wind measurements using Doppler shifts obtained from each rotation. SpiDAR is manufactured by Pentalum Technologies. This system generates conical scanning beams with a full cone angle of 5 degrees. The wind speed and direction at any height up to and including 200 m can be derived as a generalization of the cross correlation among air densities. Galion is manufactured by SgurrEnergy. In this study, 2D vertical scans (RHI scan) of the wind field were performed by varying the elevation angle of the laser while keeping the azimuthal angle fixed.

Concerning ZephIR and SpiDAR, the coefficient of correlation of each LiDAR system was greater than 0.9; however, the slopes of the approximate curve were different between NW and NNW, and SE and SSE. Nacelle anemometry measures one point, while LIDAR systems measure average wind speed from the measuring surface. Therefore, LiDAR systems have a different measurement result by the terrain conditions. It is assumed that slopes are different between the NW and NNW winds that do not flow over the mountain ridge and the SE and SSE winds that flow over the mountain ridge. The difference between the wind direction slopes is larger in ZephIR-nacelle results compared with the SpiDAR-nacelle results. This result can be attributed to the size of the measurement surface.

The Galion-nacelle slopes of the approximate curve for different wind directions show a different trend compared with LiDAR systems. It is assumed that the measurement position of the Galion system is different from the ZephIR and SpiDAR system measurement position and the Galion system is affected by accelerated flow from the NW and NNW directions.

Stakeholder Management and Legal Procedures for Setting Up Offshore Wind Projects in General Sea Area

Kimiaki Yasuda and Ryohei Fukada

Nagoya University

Abstract:

Murakami city in Niigata prefecture, Niigata Prefectural Fishery Cooperation, and Niigata Fisheries Co-operative Association decided to promote a full scale commercial offshore wind power project. They designated 27 square kilometers of general sea area off the coast of Iwafune port as an area to be used for a commercialization study on a full scale bottom fixed offshore wind power generation project. Since there is currently no full scale commercial offshore wind farm in general sea area in Japan, they faced complex issues and took several measures in order to set up the project.

Murakami city took the lead in building consensus among the local residents. It held several meetings for the local residents and relevant parties to deepen their understandings of offshore wind power generation. Moreover, it played key roles in inviting and assessing the project proposals from the candidate developers and selecting the developers to carry out the commercialization study on the offshore wind power generation project from among the public. In addition, it conducted the administrative procedure which supported the developers' license applications for exclusive use of the general sea area.

The author of this paper engaged with the stakeholder management process of the offshore wind power generation project as a mediator and provided advice on stakeholder management process. In this paper, he assesses the entire consensus building process throughout the project and the direction and formalities of the legal approach led by Murakami city in relation to the general sea area.

There is currently no comprehensive legal basis or concrete management method for business carried out in general sea area. In the case of offshore wind power project in Murakami city, the legal basis for promoting the project was based on National Property Act and prefectural ordinances. In addition, the local government took the lead in building consensus and putting out an open call for the developers of project. In consequence, it is considered that the project complemented the existing legal system and mitigated the legal risk in relation to the adequateness of the project site and developers.

Mapping Local Climate Protection and Regional Development Projects

Daniel Kremers[1], Franz Waldenberger[1] and Christian Dimmer[2]

[1]German Institute for Japanse Studies (DIJ), [2]Waseda University

Abstract:

In my poster presentation I would like to present our digital database on "Mapping Local Climate Protection and Regional Development Projects". I would like to discuss our goals and methods with experts and activists in the field of community power.

Two of Japan's most pressing topics on the domestic political agenda are regional revitalization and energy security. These questions are tightly connected to international trade and climate protection on the global level. Community Power, that is local ownership of Renewable Energy Technologies (RET), can be a strategy to tackle these two issues at the same time.1

Active citizens and local governments in Japan have already started to face these challenges and have successfully invested in renewable energies, energy saving, recycling and the use of local resources. Such initiatives, while contributing to climate

protection may at the same time improve local fiscal conditions, stimulate the local economy and strengthen social cohesion. However the knowledge, experience and possibilities of Japanese municipalities and local communities is unequally distributed inside Japan and not well known in other countries. To improve international knowledge exchange we have developed a multilingual database on local climate protection and community power in Japan.

Together with Japanese municipalities, civil society organizations and social entrepreneurs, the DIJ established a trilingual digital database and an interactive online map for regional development and climate protection projects conducted by citizens and municipalities in Japan. The project aims to not only support related research, but to also foster the exchange of information about the many climate protection initiatives undertaken across Japan among stakeholders and policy makers within Japan as well as abroad.

We are aware that there exist already a variety of databases, maps or list of projects related to renewable energy or regional development. We will build on these existing databases to establish an integrated and comprehensive database on projects that combine climate protection with regional revitalization at the municipal level. Other characteristics differentiating our database are:

- documentation of various projects in a systematic manner on the basis of a consistent and comprehensive list of variables, - trilingual data representation (Japanese, English and German), - open source approach with regard to data input, - open access with regard to use of data, - quality assurance through an editorial board.

A preliminary design in form of a mind map shows the information we wish to collect and share with local communities and citizens in Japan and all over the world. At the center of the Database are individual projects, like wind parks, small hydro power plant, or biomass plants. On the left side we have listed the technical aspects of the project in concern, while on the right side you see a list of organizational features of each project, such as name, location, date, owner etc.. This information will then be linked to public available information of the municipalities' size, industrial layout, geography and climate. We hope that this will help municipalities and citizens enable to see similarities and patterns and thus empower them to think about strategies for climate protection and renewable energies in their own municipality.

The initial stage of the project is funded by the Climate Fond of the German government. Further support is provided by the German Institute for Japanese studies to ensure long term sustainability. Now we are looking for Partners to support us with their expertise and information.

1 C. SCHICK, S. GSÄNGER, J. DOBERTIN: „Headwind and Tailwind for Community Power – Community Wind Perspectives from North-Rhine Westphalia and the World" (WWEA Policy Paper PP- 01-16).

Study on Acceptance in the Context of Absence of Local Participation to Wind Energy: Case studies in rural area of China

Qian Wang

Nagoya University

Abstract:

This article explores the current acceptance circumstance of wind energy by investigating in rural areas of China. Although numerous studies have been undertaken the acceptance research on renewable energy, no definitive explanation model has yet been found, especially on Chinese cases. This article used the social constructivism theory to explore and explain the "gray" acceptance status of China. It indicated that the question of what shapes the acceptance behavior is a complex one that cannot be visualized distinguished through without actively opposed actions. Then analyzes the causes why formed the "tolerance" and "silence" situation to wind energy in China.

It points that diversity and limitation of cognition, cultural norms and social norms, experience of public participation make synergies effect on the residents' acceptance of wind energy in rural areas of China. Motosu and Maruyama's (2016) study noted that people have negative attitudes towards a new wind farm while they accept the existing local wind farm in the context of silent acceptance condition in Japanese cases. However, Chinese cases are different from this founding and in actual residents are tolerant or complained with the existing wind farm with unvoiced status usually have no effective influence on further wind development. This reveals that passive acceptance trending not always leads obviously opposed behavior towards improve wind energy in China. The main reasons for leading this phenomenon are the property of wind energy and absence of local participation in the process of developing. Therefore, this article attempted to develop a feasible model to incorporate the related factors, such as factors that shaped the currently acceptance condition and factors that will impact the further wind development, to help illuminate the complex field of acceptance. Then give a practicable approach to encourage local participation and improve justice of China, and promote sustainable development of wind energy in the further.

A comparative performance study of Different Wind farm layout Configurations on a flat terrain of Kayathar, India.

Hardik Ashwin Naik[1], Prashant Baredar[1], Vilas Warudkar[1], Boopathi K[2] and Dr. Gomathinayagam S[2]

[1]Maulana Azad National Institute of Technology, Bhopal, [2]National Institute of Wind Energy, Chennai

Abstract:

A wind farm is the group of wind turbines in the same location used for producing electricity. Performance of any Wind Farm depends on the wind characteristics of the site and the wind farm layout configurations followed by the developer. Different configurations in a wind farm layout can be formed by varying the spacing between the turbines in the downwind side or crosswind side. The proposed study is undertaken to calculate the net annual energy generation in each of the different configurations and then compare with the output of the standard configuration currently exercised in the entire state of Tamil Nadu. Different Customized configurations have also been studied here and are expected to generate more satisfactory results than the present standard configuration. The study is done on a flat terrain of Kayathar in Tamil Nadu state of India and the energy simulation is carried out using WAsP flow modeling tool.

Site Specific Evaluation Methods by Aero-elastic Wind Turbine and LES Time Variant Wind Models Combined

Shigeo Yoshida[1], Takanori Uchida[1], Omar MOHAMED ALI MOHAMED Ibrahim[2] and Yasushi Kawashima[3]

[1]Kyushu University/Research Institute for Applied Mechanics, [2]Kyushu University/Interdisciplinary Graduate School of Engineering Science, [3]West Japan Engineering Consultants

Abstract:

(Background)

Site specific evaluation is essential for wind farms as it affects to the economics of the wind farms such as energy production, costs of maintenance and repair, in addition to financing and insurances. Furthermore, it is required in many countries by the authorities. Detailed wind conditions, such as average, spectrum, and coherence, average wind shear and so on, are necessary for the evaluation. Although, all of the wind conditions are available in the design standard or guidelines for the design of wind turbines, but those standard conditions are not applicable to the site validation directly. They are defined by combining measurements and numerical analysis in most cases, as spatial distributions are necessary for the evaluation. Local area CFD is commonly used for that in particular in complex terrain. In particular, LES (Large Eddy Simulation) is a useful tool to reproduce the characteristics of the wind in complex terrains.

(Objectives)

A wind model converter, which directly converts the time history of three dimensional wind speed from LES into input or aero-elastic codes as FAST or BLADED, was developed for site specific evaluation of wind turbines.

(Results)

A case study was carried for the #3 wind turbine in Taikoyama wind farm of Kyoto Prefecture, a typical complex wind farm in a complex terrain, at 8.1m/s of average wind speed from WNW. Time and space variant wind were calculated by RIAM-COMPACT. Two different winds were assumed here. The first one is LES output and the other one is Kaimal model with average wind shear and turbulence intensity at hub center are same as those of the LES. A model of the 750kW wind turbine was defined as well as the variable speed controller, and aero-elastic simulations were conducted by BLADED. Through the case study, the LES was shown to express complex wind characteristics in the complex terrain such as spatial variations of wind shear in particular long term variation. It affects to the load fluctuations in rotor speed and blade passing frequency. Furthermore, evaluations based on average wind shear, standard power spectrum, are suggested to be too optimistic.

CFD Simulations of Wind Turbines in Complex Terrain

Omar Mohamed Ali Mohamed Ibrahim[1] and Shigeo Yoshida[2]

[1]Kyushu University/Interdisciplinary Graduate School of Engineering Science, [2]Kyushu University/Research Institute for Applied Mechanics

Abstract:

(Background)

Terrain shape of wind farms must be considered during the process of wind farm layout optimization as the terrain can have a great impact on the total power generated by the wind farm and the life time of wind turbines.

(Objectives)

Several Computational Fluid Dynamics (CFD) simulations were carried out to investigate the effect of complex terrain on the performance of wind turbines.

(Results)

The turbulence model used was the Large Eddy Simulation (LES) model. Terrain shape was a steep two dimensional hill. Fully resolved wind turbine blades were used in these simulations. Wind turbine blades were located at different positions over the complex terrain to investigate the effect of complex terrain on power output, study the development of wakes over complex terrain, and obtain the distribution of wind speed and turbulence intensity along the complex terrain.

CFD simulations showed that complex terrains greatly affect wind turbine performance. Power output changes according to the position of the wind turbine over the complex terrain, and wind turbine wake development in a complex terrain are different from that in a flat terrain.

The work presented here is part of a project being undertaken to develop a wind farm layout optimization method that takes into account the wind farm terrain shape.

Stereo videography for bird impact assessment

Toru Takeuchi, Nakajima Chikahito, Norihiko Itoh and Masaki Shirai

Central Research Institute of Electric Power Industry

Abstract:

The impact of wind power generation on birds has been concerned in many parts of the world. In order to reduce the impact, evaluating bird collision risk has become common through environmental impact assessment. Direct observation of bird flight in wind farm is required for the risk assessment, although it is difficult for observers to record the 3D positions of rapidly moving birds in the wide range. We developed practical methods using stereo videography to reconstruct bird flight positions, covering wide range from camera to the target birds. We devised several methods for obtaining geometric relationships between cameras in outfield required for stereo reconstruction. Our filed study demonstrated successfully obtaining three dimensional coordinates of flight trajectories for six species in wide range over 200 m from the cameras. We also examined bird speeds over varied heights and constructed density map of bird position in 3D, which can be powerful information for specifying spatial use of local population for each species. Our procedure allows the collection of bird positional data in 3D space remotely and precisely for long period of time by easy and repeatable operation, leading to new stage for bird impact assessment.

A study of the turbulence and gust by the LES wind simulation of the complex terrain with the atmospheric stability

Takeshi Kamio, Makoto Iida and Chuichi Arakawa

The University of Tokyo

Abstract:

The authors carried out the Large Eddy Simulation (LES) wind simulations of the complex terrain considering the atmospheric stability and discussed the turbulence and gust characterization of the results. Since onshore wind resources are still important in Japan and the ""repowering"" will be growing trend, the developments of the analysis techniques for the onshore wind are still essential. The numerical wind simulation will be useful for the analysis of onshore complex terrain site and the effects of the atmospheric stability must be discussed. In this study, the turbulence intensity and gust from the simulations with the different atmospheric stabilities are compared and discussed.

The atmospheric stability is related to the heat flux in the atmosphere, and it is expressed by the parameters like the Bulk Richardson number or the Obkhov parameter. The number of the studies on the atmospheric stabilities in the wind energy is increasing recently, and most of the studies are focused on the offshore sites because European countries have many offshore wind projects. The effects of the atmospheric stability will be relatively strong at the offshore sites. At the onshore sites, the effects of the turbulence by the complex terrain will be stronger than those of the atmospheric stability, but those must not be ignored.

In this study, the LES simulations were carried out for the analysis of the real complex terrain in Japan. The simplified wind and atmospheric conditions were prepared to compare the effects of the atmospheric stability. The three different stability conditions were prepared: Stable condition, neutral condition and unstable condition. Those conditions differed in the vertical distribution of the temperature and, especially, the unstable condition was prepared by using the function by Wilson.

The different atmospheric stability condition cases were simulated by the LES code, which was developed by the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). The LES code is the compressive Navier–Stokes equations code with the Smagorinsky-Lily subgrid scheme, yin-yan grid, fifth finite differential method for the advection terms, the fourth finite differential method for the non-advection terms, and the third Runge-Kutta method for the time integration. The spatial resolution in the simulations was higher than those of the authors' previous studies, and smallest cell size was approximately 2.5m. The 10-min averaged wind speed and turbulence intensity were calculated from 1 sec interval samples.

The results shows that the turbulence intensity of the unstable case was larger than the stable case, the wind spectrum of the unstable case indicated the larger value in the lower frequency area than that of the stable case, and the maximum gust value in 5-sec window of the unstable case was larger than that of the stable case. The effects of the atmospheric stability will be found even if at the onshore complex terrain site, and the effects will appears as the increase of the turbulence intensity and gust value.

Impact of multi-model ensembles on probabilistic forecasts of wind power ramps in Japan

Masamichi Ohba, Daisuke Nohara and Shinji Kadokura

Central research institute of electric power industry

Abstract:

Weather events can interrupt the spin of wind turbines in large scale that cause unexpected “wind ramp events”. In this study, we present an application of self-organizing maps (SOMs) for climatological attribution of the wind ramp events and their probabilistic prediction. The SOM is an automatic data-mining clustering technique, which allows us to summarize a high-dimensional data space in terms of a set of reference vectors. The SOM is applied to analyze and connect the relationship between atmospheric patterns over Japan and wind power generation. SOM is employed on sea level pressure derived from the JRA55 reanalysis over the target area (Tohoku region in Japan), whereby a two-dimensional lattice of weather patterns (WPs) classified during the 1977?2013 period is obtained. To compare with the atmospheric data, the long-term wind power generation is reconstructed by using a high-resolution surface observation network AMeDAS (Automated Meteorological Data Acquisition System) in Japan. Our analysis extracts seven typical WPs, which are linked to frequent occurrences of wind ramp events.

Probabilistic forecasts to wind power generation and ramps are conducted by using the obtained SOM. The probability are derived from the multiple SOM lattices based on the matching of output from TIGGE multi-model global forecast to the WPs on the lattices. Since this method effectively takes care of the empirical uncertainties from the historical data, wind power generation and ramp is probabilistically forecasted from the forecasts of global models. The predictability skill of the forecasts for the wind power generation and ramp events based on the multi-model ensembles show the relatively good skill score under the downscaling technique compare with that based on the individual ensemble forecast. It is expected that the results of this study provides better guidance to the user community and contribute to future development of system operation model for the transmission grid operator.

Probabilistic Prediction of Wind Speed Ramp Events using a Regional Ensemble Prediction Method

Daisuke Nohara, Masamichi Ohba and Shinji Kadokura

Central Research Institute of Electric Power Industry

Abstract:

Abrupt change in wind power generation, known as ramp events, due to fluctuating wind speeds present challenges to the stability of the electric power supply. In Japan, ramp events are generally induced by extratropical cyclones along their track. Probabilistic prediction can be effective in predicting the behavior of such cyclones. For this study, we developed a regional ensemble prediction method using the Weather Research and Forecasting model (WRF) to provide probabilistic weather prediction for ramp events. To obtain dynamically consistent perturbations with a synoptic weather pattern, both initial and lateral boundary perturbations were determined by differences between the control and an ensemble member of the Japan Meteorological Agency (JMA)'s operational one-week ensemble forecast. This method provides multiple ensemble members with a horizontal resolution of 15 km for 48 hours at 30 minutes interval outputs by downscaling JMA's operational global forecast along with the perturbations. The predictions were able to represent various features of the high-resolution spatiotemporal distribution of precipitation affected by the intensity and location of extratropical cyclones in each ensemble member. Although the ensemble prediction showed model bias in the mean values and variances for certain variables such as wind speed, the ensemble prediction has the potential to provide probabilistic information on the timing and amplitude of ramp events.

How can we use Doppler LIDAR with simulation model in offshore wind resource assessment? (Vertical Doppler LIDAR and CFD model)

Mizuki Konagaya, Toshinari Mito and Hideki Kato

E&E Solutions Inc.

Abstract:

The effectiveness of vertical Doppler LIDAR in offshore wind recourse assessment was examined with a Computational Fluid Dynamics (CFD) model, using wind data which was observed at Floating Offshore Wind Mast (FOWM) as verification value. In this study we replicate offshore wind condition using MASCOT as CFD model which can calculate by fine spatial resolution and is adapted to the complex terrain for understanding impacts of terrain in detail. In order to implement CFD model, wind observed data at an appropriate reference point is necessary as input data of the model. The reference point in this study is set at the island about 2 km away from FOWM, and we used the observed wind data at the reference point as the input data to estimate offshore wind condition.

The estimation result of offshore wind condition at FOWM for a year, which was calculated by using wind data observed at onshore wind mast (40m height) as input data, showed a 1.5% bias on annual average wind speed. Specifically, the monthly biases were seemed to be larger, and the biases were seen significantly large especially from July to September up to 30%. This indicates that the estimation accuracy of the CFD model can be significantly reduced due to the seasonal differences in wind direction characteristics. Because the input wind data of the CFD model is affected by the surrounding environment such as terrain and trees around the observation point, it is believed that there is limitation of estimation when using such data as an input of the CFD model.

Therefore targeting the season of low estimation accuracy, the same estimation study was carried out using observation data from a Vertical Doppler LIDAR in addition to the onshore wind mast (40m height) as the input wind data. The estimation result of offshore wind speed using the onshore wind mast (40m height) showed about 15% overestimation bias in the period of two and a half months. On the other hand, when the LIDAR data observed at the same point was used as input of the CFD model, the estimation accuracy of the model was improved especially using LIDAR data observed at high altitude. The estimation bias of average wind speed was improved to about 7 % using the observation data at the 200m height, and about 9% improvement (16.5% to 7.8%) of RMSE was shown in the period.

This result indicates that Vertical Doppler LIDAR can make a contribution to improve wind estimation accuracy using CFD model. It is considered that this improvement is due to reduction of the effects affected the input wind data, which is caused from surround environment such as terrain and trees around wind observation point. Therefore, the investigation method using Vertical Doppler LIDAR is expected to become common standard for wind resource assessment in not only onshore but also offshore site.

Accuracy comparison between multiple models of vertical wind Doppler LIDAR

Toshinari Mito, Mizuki Konagaya, Hideki Kato and Yuta Matsuoka

E&E Solutions Inc.

Abstract:

In recent years, vertical-type Doppler LIDAR has become widely recognized as an efficient observation tool to measure high-altitude wind condition in wind resource assessment for installing wind farm. Vertical-type Doppler LIDAR can observe wind condition at the height more than 200m with laser beams, which is generally higher than wind observation mast. Thus, it is possible to observe wind conditions included in the highest layer which the blades reaches, even though recent trend of wind turbines are enlargement.

On the other hand, several manufacturers in various countries have been developed vertical-type Doppler LIDAR in recent years, and some of them have been validated by a third party certification agency for their measurement accuracy, especially in Europe. However, because there are some cases which the arithmetic method of wind conditions are not disclosed, some studies point out that Doppler LIDAR is such as a “black box”. And from our observation experience, it is pointed that the reason why differences of data acquisition rate between Lider models is that there are differences in the calculation settings between LIDAR models, when creating a statistics of wind conditions such as 10-minutes average wind speed value. In fact, when compared with continuous observation data in one month, the data acquisition rates are different and they depend on the models of LIDAR, like the rates are approximately 85% to 90% on average.

Therefore, in this study, we compared wind condition data observed by multiple models of vertical-type Doppler LIDAR, which are widely used internationally, with using observation data at wind masts. In addition, we compared their data acquisition rate and accuracy of each vertical-type Doppler LIDAR, and consider the characteristics between each models.

Experimental study on the air resistance of the aerodynamic brake of gyro-mill type vertical axis wind turbine

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Abstract:

The vertical axis wind turbine can be driven regardless of the wind direction, and has been put into practical use as a relatively small wind turbine. Gyro-mill type vertical axis wind turbine is comparatively highly effective. However, a lot of that type does not self-start. And, the range of a suitable wind speed for driving is narrow. So in a series of research, an original aerodynamic brake installed on the vertical axis wind turbine, that controls the output by using the wind drag by a mechanical control technique is developed. In this aerodynamic brake, the part where the wind drag is obtained is a plate. The aerodynamic brake of this plate is installed on the rotational axis through the shaft that is vertical to the rotational axis, and rotates with the wind turbine. The spring is installed in the part in the shaft. When the rotational speed of the wind turbine becomes higher, the plate installed horizontally revolves 90 degree with its axis extending in the centrifugal force and becomes vertical, the power of the aerodynamic brake increases. The shaft returns when the rotational speed lowers and the brake power decreases. In the study, the output characteristic of the 300W gyromill type vertical axis wind turbine that installed this aerodynamic brake is experimentally examined compared with the case without the plate, the case with two plates and the case with four plates. As a result of the wind tunnel experiment, the shaft expanded when the rotational speed rose as expected and the output was controlled. Output of 300W was obtained at higher wind speeds in the more use a lot of plate. That is, the range of driving was able to be extended up to wind speed 20m/s by the aerodynamic brake with two plates, and 25m/s by the aerodynamic brake with four plates, though it stopped by wind speed 15m/s when the aerodynamic brake was not put up. As a result, it is confirmed that the range of the wind speed that is able to be driven safely is extended greatly. In addition, the air resistance force that the plate is subjected is discussed.

Research of electric power regeneration using automotive cooling fan (Validity evaluation of fan-turbine system)

Shinichi Oda

Nagoya Institute of Technology

Abstract:

Automotive cooling fan mainly operates at low vehicle speed and rarely operates at the high speed of 100km/h. Therefore this work aims at developing a fan-turbine that operates as a cooling fan at low vehicle speed and operates as a wind turbine at high vehicle speed. We confirmed that the fan-turbine generates 48W at the vehicle speed of 100km/h by the results of vehicle test and the simulation using the performance characteristic, while the current fan generates about 8W at the same vehicle speed. The amount of the power generation by the fan-turbine is equivalent to the power consumption of LED headlight. Furthermore we confirmed that fan-turbine reduces 20% of vehicle power loss caused by pressure drop through vehicle cooling system by the results of vehicle test and CFD analysis.

The increase of power generation is mainly caused by the improvement of the blade profile and the rotor solidity. The current fan has double circular arc blade profile and its blade solidity is about 0.5. The fan-turbine has S-shaped blade profile and the blade solidity is 1.0. When the current fan operates at the wind turbine condition, the attack angle is negative and the tip portion of the blade does not work as a wind turbine. S-shaped profile increases the efficiency at the negative attack angle and the high solidity blade can work as a wind turbine at the whole portion of the blade. The wind turbine efficiency of the fan-turbine is four times higher than the efficiency of the current fan by the above improvement.

It is normally difficult to understand the reason for the reduction of vehicle power loss caused by the pressure drop through a cooling system at the wind turbine operation. Based on the result of vehicle test and CFD calculation, it was found that even if the pressure drop through the rotor is increased at the same vehicle speed, the total pressure drop through a cooling system does not change and it depends only on the vehicle speed and the shape of vehicle body. That is caused from the following reason. The increase of the pressure drop through a rotor causes the decrease of air flow rate through a cooling system and the decrease of the pressure drop through heat exchangers and others. The total pressure drop through a cooling system is the sum of the pressure drop through the rotor and the heat exchangers and others. When the velocity through the cooling system is less than 20% of the incoming velocity toward the vehicle, the total pressure drop through a cooling system does not change by the change of pressure drop through the rotor. Therefore vehicle power loss that is defined as the multiplication of the pressure drop and the air flow rate, decreases when fan-turbine operates as a wind turbine.

From the above results fan-turbine can regenerate electric power and reduces the vehicle power loss at the same time. Therefore fan-turbine can operate during both conditions of vehicle traveling and deceleration.

Study on Flow Field of a Straight-bladed Vertical Axis Wind Turbine by Wind Tunnel and Field Experiment

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Abstract:

With the increasing focus on off-grid energy generation, the application of small wind turbine in the urban and remote areas has been increasingly contributing to the energy needs because of its independent power generation system. Airfoils of straight-bladed Vertical Axis Wind Turbine (VAWT) may be of uniform section and non-twisted, producing them relatively easy to fabricate and extrude. Furthermore, the transmission losses are reduced due to proximity to the demand center compared to HAWT. Therefore, the design and optimization research on a straight-bladed VAWT has become one of the hot spots.

However, the critical disadvantage of VAWT is that the flow field characteristics are very complicated during rotation, because the resultant wind velocity and angle of attack to blade are periodically changing, especially at low tip speed ratios. The complex flow field, associated with a turbulent wake behind the wind turbine, can cause flow separation and vortex shedding from the blade surface. Therefore, it is very important to analyze the aerodynamic characteristics of the blades of VAWT during ration.

A test prototype is presented in this paper to investigate the uncertainties flow field concerning two experimental methods: wind tunnel experiments and field experiments. In this study, the test wind turbine is two-bladed VAWT with a diameter of 2.0 m and the blade span of 1.2 m. The airfoil profile is a symmetric NACA 0021 with a chord length of 0.20 m.

In wind tunnel experiments, the rotor rotational speed and torque can be measured by a torque meter which is installed in rotor shaft of wind turbine. In order to investigate the flow characteristic around blade surface and near-wake of wind turbine, Particle Image Velocimetry (PIV) probe is mounted to a 3D positioning device in the upper part of the test section to determine the local wind velocity at any positions in the test section. Finally, the forces and the moments applied to the entire wind turbine in the x, y and z-axes directions are predicted with a six-component balance which is located on the basement of wind turbine.

In field experiments, the value of inflow and wake are measured through three cup-type anemometers and ultrasonic anemometers. Wind direction is measured through a wind vane. The inflow velocity is measured through measurements masts set in the same height as the center height of blade span. Field experiments are carried out under the conditions of the natural wind velocity and the blade pitch angle is an optimal value, corresponding to a maximum power coefficient.

Finally, the characteristics of power coefficient and flow field are compared, according to wind tunnel and field experiments. As a result, it is clarified that the expansion of wake deficit area is promoted with the increase of tip speed ratio. Furthermore, the wake velocity in field test enables a quicker recovery than that of wind tunnel experiments. This study proves a better understanding of flow field characteristics of wind turbine and also has a guiding significance for the design and optimization of the straight-bladed VAWT.

The Development of An Innovative Small Wind Power Generator

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Abstract:

According to Ministry of Economic Affairs Bureau of Energy statistics in 2000, Taiwan has the world's first of eight countries which can manufacture large wind turbines (2MW). Taiwan is expected to complete ""one thousand wind turbine"" plan in 2030, on land and offshore, a total installed capacity will reach 4,200 MW. The wind power industry development in Taiwan, more or less focus on the component development such as motors, blades, etc. and the signal failure analysis of the components. In consideration of the economic benefits, the study will focus on improving the small fan

This paper presents an innovative wind mill structure design together with a motor system could provide comprehensive wind speeds response to get high performance fan. In order to achieve a low starting wind speed fan, we integrated from the structure design and a motor self-control system. The motor self-control system consists of a disc coreless permanent magnet generator to improve the low wind speed startup problems and a steady speed design. The permanent magnet brushless DC generator, a so-called Cogging Toque or no-current torque which come from the iron core between the teeth on the rotor magnet and the stator coil. The steady speed design of the wind turbines with power split transmission, regulated device for overload input power, diverted to a backup generator, to expand the wind power suitable wind speed range. Instead of traditional electronic control unit(ECU), the indigenous centrifugal clutch had installed between the generators and automatically connected number generators based on different wind speed; strong wind speed trigger more generators by using centrifugal clutch to increase the power generation efficiency ; Conversely, when the wind speed decreases, the centrifugal clutch will automatically release the array of generators to maintain generator rated power without extra power supply and complex protection system.

The test is operating in electrical machines laboratory and essentially test to determine the characteristics of prototype generator. Based on the experiments, the Off-load start point is at wind speed 2 m / sec. Besides, a high wind speed (e.g. 40m/s) runtime, the system maintenance at constant 350rpm high torque. The output power can achieve 400W. Furthermore, the prototyped of the generator is relatively small and cheap. After the fabrication and testing of the prototype, this system has been proved feasible for practical application.

UTILIZATION OF INTERNATIONAL CERTIFICATION SCHEME IN JAPANESE OFFSHORE WIND FARM

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Abstract:

This paper introduces necessity and importance of utilization of the International Technical Certification Scheme developed by IEC(International Electrotechnical Commission)/ISO(International Standard organization) of wind turbines, for the safe and successful wind farm projects.

In Japan, there is a strong expectation for offshore wind farm because of its huge, world sixth largest Exclusive Economic Zone. On the other hand, there are some sever and typical meteorological condition in east Asia, for example typhoon, earthquake, tsunami and lightning, all of which could be a threat to offshore wind farms in Japan.

Regarding wind turbines, IEC/ISO has been developing various international standards and certification scheme as follows. We should utilize those conformity assessment scheme by certification bodies for the sake of both safety and stability of wind farm business.

1. Type certification

Type certification is a procedure by which a certification body gives written assurance that a wind turbine type conforms to specified requirements. It applies to a series of wind turbines of common design and manufacture. It consists of the mandatory modules:

- design basis evaluation; - wind turbine design evaluation; - type testing; - manufacturing evaluation; and- final evaluation

2. Project certification

Project certification is a procedure by which a certification body gives written assurance that one or more specific wind turbines including support structure are in conformity with requirements for a specific site.

Its purpose is to evaluate whether type-certified wind turbines and particular support structure/foundation(s) designs are in conformity with the external conditions, applicable construction and electrical codes and other requirements relevant to a specific site.

Project certification of type-certified wind turbines usually consists of the following modules:

- site conditions evaluation; - design basis evaluation; - integrated load analysis; - site-specific wind turbine/RNA(rotor nacelle assembly) design evaluation; - support structure design evaluation; - other installations design evaluation; - wind turbine/RNA manufacturing surveillance; - support structure manufacturing surveillance; - transportation and installation surveillance; - commissioning surveillance; - final evaluation; and - operation and maintenance surveillance.

In Japan, there are some offshore wind projects planned, and those results would have a great influence on following projects, so that we have to try to show a success model of Japanese offshore wind farms at first by making effective use of above certification schemes.

Effect of leading-edge protuberances on the aerodynamic performance of airfoil

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Abstract:

From the flipper of marine fish body, it can be well known that, the rounded tubercles on the leading edge acts as the boundary layer control devices to improve the hydrodynamic performance. This boundary layer control may increase the wind turbine output. When wind turbines are operated with large variance of wind speed, the turbine blades receive large change of attack angle. These high turbulence winds occur near ground surface. Therefore, this study aims to develop a new airfoil for wind turbines, which has superior power performance under the conditions of high turbulence intensity. Before the wind turbine rotor application, it is very necessary and important to clarify the steady and unsteady aerodynamic performance of the airfoil with different turbulence intensities.

Wind tunnel experiments are conducted with a Gottingen circular type wind tunnel in Mie University. The balance measurements are performed to evaluate the sectional performance for static stall and dynamic stall of 2D airfoil section with tubercles. The main sectional profile is a symmetric NACA 634-021 airfoil with a chord length of 0.20 m. The test airfoil sections are set on rotary disc which is installed on side walls of the measurement section. In this study, the free stream wind velocity is 15.0 m/s and the Reynolds number is 2.0 × 105. The turbulent flow is generated using turbulence grids. The four types of turbulence grids are used to set different turbulence level. The angle of attack is set by a servo motor with resolution of angle is ± 0.02º.

Firstly, this study focuses on the evaluation of aerodynamic forces in the low turbulence flow with some angles of attack. The sectional forces and moments act on the airfoil models are measured by a three-component balance. The several protuberances are set at the leading edge of test airfoils. After that, static turbulence grids are used to estimate the effects of different turbulence intensities on the airfoil performance of the lift and drag forces. Furthermore, the dynamic stall phenomenon of the leading edge protuberances airfoil is also investigated at some different turbulence intensities.

In this study, an experimental investigation has been undertaken to determine the influence of sinusoidal leading edge protuberances on the aerodynamic performance of some airfoils with different turbulence intensities. As a result, it can be found that the developed leading edge generally shows higher lift to drag ratio than that of baseline at high angles of attack region. This study has a guiding significance for the design and development of a wind turbine suitable for high turbulence intensity, according to optimizing the leading edge protuberances airfoils.

Concealed Multi-Rotor Ducted Wind Turbine

Allen Kwok Fai Chan

Independent Inventor

Abstract:

The present application is directed to a concealed multi-rotor tangential fan wheel wind turbine system comprising: a plurality of tangential fan wheels to be housed inside the cavity of a rotor blade in the manner that their axles are coupled along the same common axis such that high speed wind from the external environment may be drawn into the rotor blade through the openings on the leading edge of the rotor blade as the rotor blade rotates hence driving the tangential fan wheels to spin at a couple thousands r.p.m. thereby the rotating torque of the tangential fan wheels may be transmitted via an transmission shaft to a high speed generator located at the root of the rotor blade for power generation, wherein the high speed generator may be further extended to be located at the hub wheel alternatively. The incoming wind may be drawn into the inside of the rotor blade at the speed of $2\pi R$ times the r.p.m. of the rotor blades, 'R' being the average distance of the openings on the leading edge of the rotor blade from the axle of the rotor blades, and then to be discharged to the open air via the vents on the trailing edge close to the root of the rotor blade. Since the incoming wind speed may be in couple tenths of meter per second capable for driving the tangential fan wheels, which being coupled to the said high speed generator, to generate electricity directly without the engagement of step-up gearbox and bulk generator inside the nacelle. As such, drastic saving in the initial investment and subsequent operation costs may be achieved since a gearbox dominates at least 13% of the total set up cost a wind turbine whilst gearbox replacement has to be implemented every 5 years in accordance with the American insurance policy for wind turbines.

Gravity Induced In-plane Self-excitation of 2-bladed Flexible Rotor

Shigeo Yoshida

Kyushu University/Research Institute for Applied Mechanics

Abstract:

(Background)

The 2-bladed rotor is one of the promising concepts to emerge from the study of super large wind turbines. On the other hand, the rotor is prone to generating larger vibrations compared with conventional 3-bladed rotors. In particular, in-plane vibration is hard to avoid because its damping is generally small, and it is hard to mitigate by the blade pitch control. Furthermore, blades are becoming more flexible as wind turbines are getting larger.

(Objectives)

The mechanism of the in-plane self-excitation of a large scale wind turbine with a 2-bladed rotor was studied through aero-elastic simulations.

(Results)

In cases structural properties are similar, large rotor in-plane self-excitation occurs in 2-bladed rotors, but does not 3-bladed rotors. The self-excitation was shown to be caused by a combination of blade in-plane elasticity and gravity. Furthermore, the mechanism was theoretically demonstrated through simplified models that showed a mass and a spring. It also showed the rotor mass center of the 2-bladed rotor moves in-plane, but that of the 3-bladed rotor does not. These differences affect the rotor in-plane excitation.

The excitation is expected to increase as the size of the wind turbine increases as it is caused by the blade flexibility. Hence, a 2-bladed rotor is more challenging in larger scale wind turbines.

Inflow Coherence Effects on Multi-Rotor Wind Turbine System

Shigeo Yoshida and Yuji Ohya

Kyushu University/Research Institute for Applied Mechanics

Abstract:

(Background)

Multi-rotor system (MRS), which equipped with multiple wind turbines on one tower, is a promising concept for super-large wind turbines as over 10MW, due to its perspectives in cost and weight. As individual wind turbines are distributed in large area, coherence is expected to affect the dynamics of load and power output. And, although the decay constant in IEC61400-1, ed.3 recommends a decay constant C=12, wide ranging of measurement data are reported from C=6 to 24.

(Objectives)

Aero-elastic simulations were conducted to evaluate the effects of coherence decay constants on fatigue loads of large scale MRSs.

A model of a 14MW MRS, which consists with 7 units of 2MW turbines, and wind models with three decay constants C=6, 12, and 24 were defined for that.

(Results)

- The effects of coherence are different between collective (tower-base fore-aft bending, power, etc.) and differential (tower-top nodding, yawing, etc.) loads. Larger coherence causes larger fatigue damage for the collective loads. On the contrary, it causes smaller fatigue damage for the differential loads.
- In the most significant case, fatigue damage of the tower-base fore-aft bending, which is one of the typical collective loads, was more than doubled between C=6 and C=12.
- However, MRSs are still out of scope of the present IEC61400-1 standard, the coherence should be defined carefully in the design of large scale MRSs, as it affects to the design significantly.
- The effects of decay constant shown here depend on the size and numbers of MRS.

Influences of Rotor Thrust on Tower Shadow Effects of Downwind Turbines

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Abstract:

(Background)

Although most of wind turbines have upwind rotor, downwind turbines are getting popular due to its advantages in performance and safety in complex terrains. Furthermore, downwind rotor is thought to be advantageous in economics for multi megawatt class super large offshore wind turbines, or in the application for floating offshore wind turbines. It's nature in stability affects to load and safety in particular in stormy conditions. However, the interactions between the rotor and the tower of downwind turbines caused many problems in the history. The phenomenon is well known as \"""tower shadow effect\""". In other words, appropriate tower shadow models are essential to utilize the advantageous aspects of downwind turbines.

(Objectives)

Considering the situations, influence of operation conditions on tower shadow effects of downwind turbines were studied in the present study, mainly through wind tunnel tests.

(Results)

The results show that larger rotor thrust is effective to reduce the tower shadow effect in blade passing frequency, in cases as followings;

- higher tip speed ratio with identical pitch angle.
- smaller pitch angle, in identical tip speed ratio.
- reduce pitch angles locally in front of the tower (individual pitch control).

System Identification and Control of Airborne Kite Power System

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[2]Kyushu University/Research Institute for Applied Mechanics

Abstract:

(Background)

Kite has a potential to be an alternative energy resource to generate power using high speed wind in high altitude. The power will be produced by the motion of the kite. In the present concept, the kite is controlled using the control pod steering system fixed on it. Electricity is generated at ground by achieving two cycle phases. These two phases make a complete loop for the kite motion. The power is generated from the reel-out phase of the tether. Harvesting the power happens when the kite takes the path ""figure of eight"". The reel-in phase starts when the tether reaches the maximum length. During this motion the generator works as motor to put the kite on the starting point again to start new traction phase.

(Objectives)

A simplified model of the kite based on the Sky Sails towing kite system was developed to apply to the controller optimization.

(Results)

Some assumptions were considered to simplify the derivation. The model is not accurate enough to describe the real flight cases; so the system identification was applied to generate the system governing equations in the discrete domain. Placket's model was used to implement the system identification.

Comparison between the model response and placket's model was presented to show the accuracy of the system identification. The pole - placement controller was applied to adapt the system parameters. The controller gains are not fixed. Gains are adapted in real-time to keep the required response. Finally, the noises are added to test the capability of system identification of representing the real flight test.

CFD Analyses of Stall Characteristics of DU96-W180 Wind Turbine Airfoil

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Abstract:

(Background)

Wind turbines are usually vulnerable to aerodynamic stall when their blades are struck by a relative wind at high angle of attack. This phenomenon occurs in storm conditions with large yaw misalignment and also in power production in turbulent wind. This will result in stall-induced vibrations which deteriorate the aerodynamic performance of the blade as well as imposing extra stresses on the blade structure through fatigue loads, and might potentially end up to wind turbine failures. Thus, accurate prediction of the stall and post-stall characteristics of the wind turbine blades is an important preliminary step towards a full understanding of the flow behavior in this critical region to reduce the design loads, hence, to reduce the cost. Consequently, this will facilitate the process of choosing the optimum control technique for delaying the separation or even reattaching it back to the surface of the wind turbine blade. Hence, the stall-related undesirable consequences could be much mitigated or even hindered and that will surely have a noteworthy practical impact on improving wind turbine power outcome at a reasonable energy cost.

(Objectives)

The objective was to make numerical simulations in order to calculate the stall characteristics of wind turbine airfoils.

Computational Fluid Dynamic (CFD) analyses were conducted for DU 96-W180 airfoil, developed by Delft University of Technology (DUT) and dedicated to wind turbines.

(Results)

CFDs were conducted using the Open-source CFD toolbox OpenFOAM, and the results were compared to those of ANSYS Fluent and validated with the experimental wind tunnel results of DUT. Various domain grids were tested to achieve the optimum grid size with the most accurate solution. Furthermore, different turbulence models were compared to settle on the best model that was able to capture the flow behavior in this critical region. The obtained numerical results were interpreted and investigated to decide on the optimum solution technique. Finally, several promising active control techniques were presented that would benefit any future trials to control this phenomenon and suppress its problems. Full study and implementation of these simulations will be shown and discussed in the full paper.