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Advanced Reseach Report for Small Horizontal Axis Wind Turbine with Double Pitch Control mechanism

Yukimaru Shimizu[1], Kiyoshi Okamura[1], Ketu Ri[2] and Den Tei[2]

[1]Nagoya Sangyo University, [2]Nagoya Sangyo Univ. Graduate student,

Abstract:

The paper describes the outline of advanced development of small horizontal axis wind turbine with double pitch control mechanism.

Multi-poles permanent magnets are used in the generator.

Two kinds of driving methods are compared in this paper. One of them is the direct connection as the generator is directly connected to the wind turbine rotor. Another one is two stage axes connection.

The generator is connected to the turbine rotor by two stage axes namely, gear box. The experimental data of direct connection turbine is compared with that of two stage axes one.

Small HAWT of direct type generates the electric power from 2.0m/s~2.5m/s low wind speed. Also, the power coefficient, Cp is a little improved, and is compared with one of two axes type HAWT.

The characteristics of the direct drive type are explained as the following.

1) The improved wind turbine has no gear box, namely, the turbine rotor is directly connected to the generator.

2) The diameter of turbine rotor is enlarged from about 3m to 3.6m.The diameter becomes large to 0.6m. As the result, the starting wind speed, namely, cut-in wind speed is improved to 2m/s~2.5m/s.

3) The large thickness aerofoil section is applied to the blade root area.

4) The improved multi-poles generator has many permanent magnets with strong magnetic force on rotor surface and many thick coils are set on the static surface side (no rotor side) of generator. As the result, a little large current can be generated in the coils.

5) The rotation speed of wind turbine is passively controled by new double pitch control mechanism to variable wind speed, and excessive rotation speed more than 350rpm can be saved.

6) It is difficult to construct a wind turbine pole on the weak soil.

One know-how is proposed to construct a wind turbine pole on the weak soil. It is explained such as the following. The weak soil are diged on 2m depth and 2m suare. Many sand bags (soil bag:no problem) are placed in two stages on the bottom. The steel frame is constructed by the welding. A wind turbine pole is standed up on the base.

In the paper, many data and results are explained.

Performance Prediction of Horizontal Axis Wind Turbine using CFD

Masami Suzuki

University of the Ryukyus

Abstract:

It is difficult to predict only by a wind tunnel experiment, because there are the problems such as the scale effect with respect to the actual wind turbine performance. Therefore, the practical use of CFD that the enough validation was made by experiments becomes more and more important in future.

In this paper, it is attempted to solve the more accurate characteristics of a wind turbine for a short time, using the coarse grid. The CFD code is an in-house incompressible finite volume Navier-Stokes solver which is developed by the author. The solver is based on structured grids and the use of curve-linear boundary fitted coordinates. The SIMPLE algorithm is used for pressure-velocity coupling. The convection term is calculated using the QUICK scheme and the other terms in space are calculated using the 2nd order difference schemes. The proven and computationally efficient Launder-Sharma low-Reynolds-number k-□ turbulence model is used in this report.

In this study, in order to validate an analysis precision of CFD, the results of two-bladed and three-bladed wind turbines are compared with ones of experiments. The accuracy of the performance prediction was investigated. The possibility that the errors overlooked by the experiments and the unprecedented phenomenon are found has been shown. In addition, for two-bladed and three-bladed wind turbines both, the predictions of the thrust coefficients and the power coefficients are in agreement with ones of experiment. The center of thrust becomes approximately constant position for both two-bladed and three bladed turbines in the high tip speed ratio. The effectiveness of the performance prediction by CFD has been shown. However the predicted thrust and power coefficients of the three-bladed turbine shift upward the experimental results. Although it is necessary to do the detailed examination, if the experimental data correct, it is presumed that a peculiar feature exist in the horizontal axis wind turbine. The efficiency is proposed to evaluate the wind turbine performance comparing with the other turbomachinery in this paper. The efficiency defined in this paper is in good agreement between the CFD and the experiment for the operation range over the higher tip speed ratio than not stall one. In this regard, it is suggested for the tree-bladed turbine that the difference results between the CFD and the experiment may be caused by a problem except CFD. It may be suggested to perform the detailed error examination which is included in the experimental device and the measurement procedure. In addition, the maximum efficiencies are 50% and 60% for the two-bladed and the three-bladed turbine, respectively. The efficiency of two-bladed turbine which has the simple blade form becomes lower than that of the three-bladed turbine.

Load Analysis of the Two-Bladed Horizontal Axis Wind Turbine by HILS

Shigemitsu Aoki and Tetsuya Kogaki

National Institute of Advanced Industrial Science and Technology

Abstract:

1. Overview

In order to make an approach according to the Load Analysis of the three-bladed small sized horizontal axis wind turbine, the basic equations were derived by Lagrange's method on Eulerian coordinate system.

An aero-elastic simulation model named AIST-RAM (AIST Real-Time Model), that calculates characteristics of the motion and the load was developed referring to the basic equations and another factors such as an aerodynamic force acting on the blades that is strongly affected by the motion and elasticity of the blades itself. Furthermore, the model was evaluated through experimental operations of a small sized three bladed horizontal-axis wind turbine which was constructed as well as the specified management system called Hard- wear in the Loop (HIL).

Through the successive evaluation by field testing accompanied with real-time simulation arranged by the Hard-wear in the Loop System, the credibility of the simulation soft-wear is gradually confirmed.

2. Background

In order to improve the technology of design and evaluation as well as the cost-reduction as to development of the small wind-turbine, the application of recent IT technology is under discussion now.Although technology of real-time simulation together with an evaluation system called Hard-wear In the Loop (HILS) is well established among the industry like automobile or aerospace, there is no successful case according to the wind-turbine industry.

3. Modeling

In order to introduce the basic equations that ordinate the inertial force acting on the system, "Eulerian coordinate system" was adopted as a generalized coordinates. Basic attitude of the rotor-blade was conducted with four degree of freedom defined as β , ψ , θ and ϕ , as is shown in Figure 1.(See. Proc. Paper) First International Symposium on Flutter and its Application, 2016 Hence β is defined as the pitch angle that adjust the attack angle around the axis approximately put on the aerodynamic center of each blade section, ψ is defined as the azimuth angle of the blade rotating on the main axis of the rotor, θ is defined as the tilt angle that starts from perpendicular position and ϕ is defined as yaw angle of the main axis according to the directional change.

4. Simulation model construction

A circumstances of time-driven simulation system was prepared to establish the construction of the model shown in Figure 2. (See. Proc. Paper)

5. Load analyses of the three bladed small Horizontal Axis Wind Turbine

Co-responding to IEC/JIS standards, the result of load-measurement in field testing was arranged to realize the fair comparison under the condition of each load case of the standards.

6. Summary

An aero-elastic simulation model named AIST-RAM (AIST Real-Time Model), that represents characteristics of the motion was developed referring to the basic equations and another factors such as an aerodynamic force acting on the blades that is strongly affected by the motion and elasticity of the blades itself.

Through the successive evaluation by field testing accompanied with real-time simulation arranged by the Hard-wear in the Loop System, the simulation model shows significant credibility and preciseness particularly for the inertial property.

Numerical Analysis of a small HAWT

Noriki Iwanaga[1], Shunsuke Negishi[1], Takashi Hashiba[1], Katsuhito Akashi[2], Hideki Kitajima[1], Hiroshi Ishikawa[1] and Kenichiro Yoshimi[1]

[1]*Research Center of Computational Mechanics,Inc.,* [2]*hiyo Aircraft Manufacturing Co., Ltd.,*

Abstract:

A small HAWT is numerically studied on its dynamical, structural, and acoustical features. The 3D structural analysis done by a commercial code after multibody dynamics calculation done by the FAST provides us the stress-strain distribution on the blade surface, which is helpful for the damage prediction. The acoustic analysis done by the FLUENT and our in-house code gives us not only frequency character but also time historical one at any observation points. As a result, impulsive sound is observed at observation points near the turbine.

A study evaluating a wind condition model for the generator output variation of a grid-connected small wind turbine

Ryo Kobayashi[1], Takeshi Kamio[1], Mitsumasa Iino[2], Makoto Iida[1] and Chuichi Arakawa[1]

[1]The University of Tokyo, [2]Ashikaga Institute of Technology,

Abstract:

Equipment certification is required for the installation of grid-connected small wind turbines in Japan. At present, the certification procedure is only available for a pair of small wind turbines and a PCS (Power Conditioning System). However, such a procedure is inefficient in terms of both cost and time. Therefore, this paper proposes a procedure for the independent certification of a PCS. It is apparent that the procedure would require the development of an output model for a small wind turbine generator. in the previous study, we confirmed that the experimental results for averaged generator output in one and ten minute matched the field results. However, some problems were faced during the evaluation of the output characteristics, such as a sudden change in the output. One of these problems was related to the wind condition model. We investigated the relationship between wind conditions and generator output during sudden changes using field data In this study, we investigated the sudden change in the generator output due to various wind conditions.

Small wind turbine simulations were executed using FAST(Fatigue Aerodynamics Structures, and Turbulence), which was developed by the NREL (National Renewable Energy Laboratory). FAST calculates wind power based on BEM (Blade Element and Momentum theory) and analyzes all mechanical components of a turbine, such as the tower, nacelle, and blades.

In this study, an investigation of a commercially available small wind turbine (NWG-1K, Nikko Company) that is suitable for grid connections was conducted.

In this study, a comparison was made between the simulation results and field data. The generator output of the NWG-1K turbine was simulated using NTM (Normal Turbulence Model), and the maximum value of the power change at 0.1- second intervals was calculated from the simulation results. The NTM is defined in the IEC (International Electro technical Commission) 61400-2, which details the design requirements for small wind turbines, and it is the turbulence model that considers the effects of varying wind speed, varying direction, and rotation sampling.

The field data and simulation results were compared in this study, and the following was concluded:

- The simulation results using the NTM were less than the field data.
- A modified NTM may be necessary to simulate the sudden changes in the generator output at 0.1- second intervals and to consider the effects of turbulence intensity.