Large-eddy Simulation of Wind for Numerical Site Calibration Technology
Phase I : Basic Study of Numerical Simulation on Complex Terrain

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Since the wind energy is strongly affected by the fluctuation of the wind, the site assessment of the wind farm in advance is significantly important. The one of the difficult problems in the site assessment is the strongly distorted wind on the complex terrain. NSC(Numerical Site Calibration) is one of the new site assessment methods and it is expected to be a solution of the distorted wind on the complex terrain. The feature of NSC is the use of the numerical simulations for the analysis and evaluation of the wind resource at the wind farm, and it would the advantage of the cost and more appropriate analysis would be available than the experimental method. Now the international discussion continues for purpose of its standardization and the goal is that NSC would be made addition to IEC61400 series, those are the standard concerning WTGS (Wind Turbine Generation Systems). To standardize NSC, there are many problems to settle and a lot of case data, those mention a lot of sites, numerical models, boundary conditions and so on, should be needed. This paper presents the numerical results of one of the research target sites in Japan and those are generated by the numerical model MSSG-A (Developed by The Earth Simulator Center, Multiscale Simulation Research Group), which is the large-eddy simulation model based on the Smagorinsky-Lilly parameterization.

Keywords: Site Assessment, Numerical Site Calibration, Large-eddy Simulation, Distorted Wind

1. Introduction

Since the wind energy is strongly affected by the fluctuation of the wind, the site assessment of the wind farm in advance is significantly important. The wind energy technologies are ruled by IEC61400 series and the methods of the site assessment is also mentioned. However, the methods are available only for the stable wind on the flat terrain, not for the unstable and distorted wind on the complex terrain. This is because the unstable and distorted wind is difficult to observe and analyze, and the turbulent wind brings the strong fatigue load to the structures of the WTGS (Wind Turbine Generations Systems) and the troubles of WTGS happen more frequently than the stable wind on the flat terrain.

The NSC (Numerical Site Calibration) is the new method suggested by the Japanese researchers for the more advanced analysis method of the unstable and distorted wind [1]. NSC is based on the site calibration, which is the experimental method of the wind analysis by measuring the wind at WTGS[2]. In NSC, the numerical wind prediction using CFD (Computational Fluid Dynamics) is used for the prediction and analysis of the wind at WTGS. This paper shows the numerical results as the first step of the standardization of NSC.

2. Numerical Site Calibration

NSC is based on the site calibration, which is the measurement method and ruled in IEC61400. In the site calibration, the winds at the two mast those are the reference mast and the measuring mast at the point where wind turbine would installed in future, are measured and the distortion factor β is calculated as $\beta = U_2/U_1$ (U_1 is the wind speed at the reference mast, U_2 is at the measuring mast).

This distortion factor is used for the prediction of the wind at the wind turbine installed in the future, and the wind

at the wind turbine is calculated by β and the wind at the reference mast that is always measured after the wind turbine is installed. The distortion factor should be given for the sixteen wind directions, so the sixteen distortion factors are given to one wind turbine. Using the distortion factors and wind prediction, the wind energy grabbed at the wind turbine could be predicted. And if those sixteen distortion factors are given to each wind turbine in the wind farm, the whole wind energy of the wind farm could be predicted.

Then, in NSC, the measuring process in the experimental site calibration is changed to the numerical wind prediction process. This means that the measuring mast is not needed and the cost of the masts is reduced and the advanced prediction of the wind conditions are available, so the position of the wind turbines would be selected more properly before the wind turbines installed, and also the whole wind energy of the wind farm could be predicted in advance.

3. Numerical Analysis

This study aims to show the numerical analysis for the standardization of NSC and the numerical condition. The authors tried the numerical analysis of the wind on the geography of the Japanese site (called as SITE-U in this paper) using MSSG-A.

In this paper, the numerical domain size is interested. This means how large area of the topography affected the wind at the target mast and the how large numerical domain should be used for the numerical prediction process.

4. Numerical model

The numerical model used in this paper is MSSG-A (Atomospheric part of the Multi-Scale Simulator for the Geoenvironment) which is developed by at the Earth Simulator Center (JAMSTEC, Japan)[3]. The features of MSSG-A are the large-eddy simulation based on the Smagorinsky -Lilly type parameterizations, the high resolution simulation, and the multiscale simulation, which can simulate the various scale - Macroscale, Mesoscale and Microscale. The authors work with the Multiscale Simulation Research Group and could used MSSG-A for the research of NSC.

5. Target Site

The target site in this paper is the relatively flat terrain site located in the south-western area of Japan and called as SITE-U in this paper. The geographical features of SITE-U are the relatively flat topography and the mountains in the north-east and the fall down in the south-west area (Fig. 1).

At SITE-U, the two masts were installed to measure the winds and the winds are measured in the 45.0 m heights of the masts, and the distortion factors β ($\beta = U_2/U_1$, U_1 is the wind at MAST1, U_2 is at MAST2) had calculated by Matsumiya and Matsushita (Kyushu University).

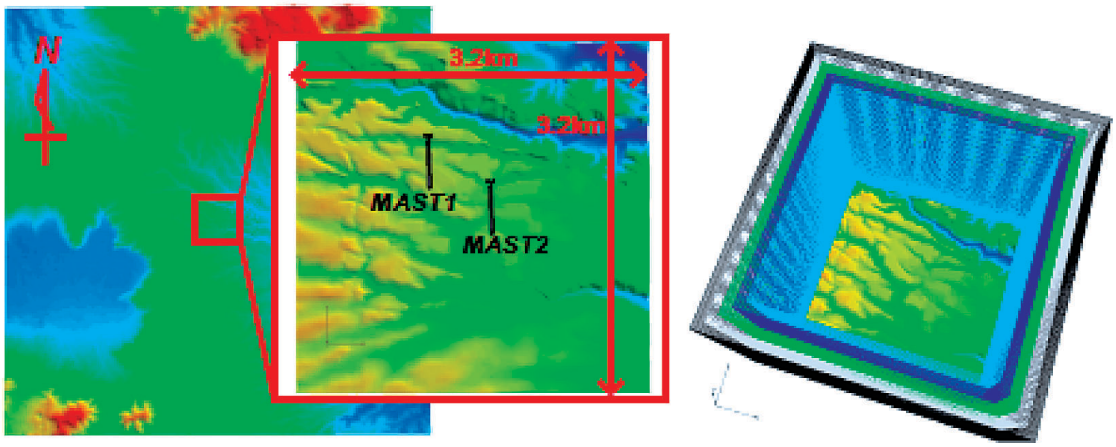

Fig. 1 SITE-U
(left: Geographical information, right: Numerical domains and grids used in this study)

Table 1 Properties of the domains and grids.

Grid	Domain size (km)	Cell size (m)	Number of Cells
g240	2.4 × 2.4 × 3.0	Horizontal: 10.0 Vertical: > 5.0	$240 \times 240 \times 64 = 3.7 \times 10^7$
g260	2.6 × 2.6 × 3.0		$260 \times 260 \times 64 = 4.3 \times 10^7$
g280	2.8 × 2.8 × 3.0		$280 \times 280 \times 64 = 5.0 \times 10^7$
g300	3.0 × 3.0 × 3.0		$300 \times 300 \times 64 = 5.8 \times 10^7$
g320	3.2 × 3.2 × 3.0		$320 \times 320 \times 64 = 6.6 \times 10^7$

6. Summary

This paper shows the numerical results of the wind at SITE-U for the purpose of the beginning of the standardization of the Numerical Site Calibration, and the numerical condition, especially the numerical domain size. The results show the various values for the domains and no integrated tends, and the results might show the inflow conditions are more effect. To make this clear, the more cases of the simulation is needed and the various type of the inflow conditions, for example use of the driver domain, should be tried.

Acknowledgement

The experimental data of SITE-U is the work by Matsumiya and Matsushita (Kyushu University).

Reference

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風力発電機性能評価のためのLES数値サイトキャリブレーション技術 フェーズ1：複雑地形における数値サイトキャリブレーションの基礎検討

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風車は単純地形の平坦地から複雑な山岳地まで、地形特性・気象特性の異なる地域で導入される。そのため、風車の性能（風速に対する出力）を正確に評価することが困難である。従来の実験的なキャリブレーションでは、風車設置位置と参照風速を計測する位置に気象マストを設置し、二つの相関関係から風車設置位置での風を推定していた。ところが、この方法では適用できる地形がごく限られた比較的平坦な地形で、日本のような複雑な地形においては適用困難である。本研究では、このような問題に対する解決方法として、数値解析によるアプローチ（数値サイトキャリブレーションと呼ぶ）を試み、世界標準化を目指す。本稿では、海洋研究開発機構で開発されたLES局所風予測のためのシミュレーションコード（MSSG-A）を用い、サイトUに対して、数値サイトキャリブレーションを実施し、その結果について検討を行った。

キーワード：数値サイトキャリブレーション, LES, 風車性能評価, 国際標準規格