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An Innovative Building Integrated Wind Turbine System

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ABSTRACT

A building integrated wind turbine module utilizing building skin is proposed to compose a hybrid-type wind-solar power generation system which creates a part of own consumed energy from locally available renewable energy sources. The proposed system is developed to have a form which wind effectively converge on. A computational fluid dynamics analysis was used to examine a proper shape of the module. Several wind tunnel tests were performed to assure numerically analyzed results and verify a performance of a model in the proposed shape. As a result, wind was augmented effectively passing through the system and measured outlet velocity highly increased. It is demonstrated that the building integrated module can raise wind speed to sufficient level to operate wind turbine installed in the module.

1. INTRODUCTION

Today, the necessity for renewable energy sources becomes greater due to limited reserve of fossil fuels and its environmental impacts, and renewable energy market such as solar panels and wind turbines grow rapidly. It is reported that its annual growth rate is not fewer than 30 % (Lars Kroldrup 2010). Among them, wind is one of the most attractive energy sources because of its cleanness, sustainability, and improved performance at present. However, many previous researches have been focused on large-size turbines and the most generated wind power is from grand-scale wind farm far from the cities while the energy consumption is concentrated in urban area. After all, an amount of energy is lost during power transmission process.

Buildings as power plant are another issue for renewable energy. Such buildings are capable of transferring surrounding energy sources to a part of consumed energy. Urban area has enough wind energy source because there occurs fast and frequent wind around building, whose velocity is faster than 5.5 m/s (CASE, 2012). Currently, there are constructed several skyscrapers such as World Trade Center in Bahrain and Pearl River Tower in Guangzhou which large-scale wind turbines are embedded inside.

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In spite of their high efficiency, these systems cannot be the solution for numerous existing buildings because they should be considered from design process. Alternatively, remarkable small wind turbines have been developed to be installable on existing buildings. However, the total output from these systems is quite low compared with previous examples due to their limited installable area such as a roof and edges of a building.

In this research, an innovative building integrated wind turbine module which exploits wind occurred on building skin is proposed. To develop a proper module shape, a CFD (computational fluid dynamics) analysis was conducted and several wind tunnel tests were performed to assure the numerical results.

2. PROPOSED SYSTEM

The proposed system is designed to be installable on building skin, previously unavailable area for wind turbine systems. As shown in Fig. 1, an applicable area of the building skin is much larger than roof area for conventional systems. A schematic diagram for proposed system is shown in Fig. 2. To exploit wind pressure on building skin, a guide vane is proposed to concentrate dispersed wind flow into rotor. Additionally, the proposed shape of the guide vane is complementary with solar panel because solar panel's efficiency increases through the inclination of solar panel (Simon Roberts et al., 2009) and the space below solar panel to emit unnecessary heat (Seo, Jung-Hun, et al, 2006). The module system is applicable to existing buildings without building redesign. For the rotor, savonius-shaped wind turbine is suggested thanks to their lower cut-in speed, safer operation, and much lower noise level than other models (Ushiyama I, et al, 1988).

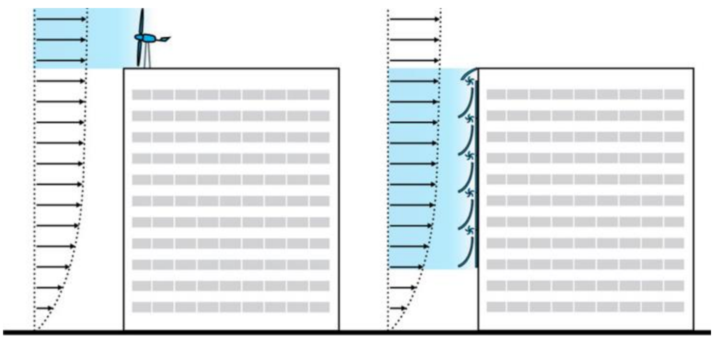


Fig. 1 Comparison with conventional systems

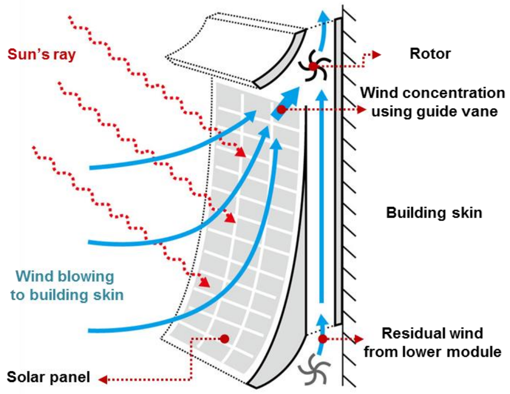


Fig. 2 Schematic diagram

3. GEOMETRICAL PARAMETRIC TESTS

In this chapter, various CFD tests are conducted to investigate geometric effects of the guide vane regardless of the rotor. In addition, several experiments in wind tunnel are performed to check reliability of CFD analysis and assure performance of the guide vane.

3.1 Numerical Parametric Tests

Commercial software FLUENT 6.3.26 is used for the CFD simulations. The solution domain and mesh discretization are generated with GAMBIT 2.2.30. For the viscous model standard k-epsilon model is used.

Area ratio and Height The solution domain shown in Fig. 3 is used to investigate effects of module's area ratio and height. Area ratio is defined as a ratio of input area to output and several cases with different area ratio value from 0.1 to 0.5 are performed. As a result, output wind speed increases with area ratio decreasing. In the parametric tests for system height, four models are modeled with different height from 0.1 m to 0.4 m in 0.05 area ratio. The average output velocity ratio decrease from 8.44 when 0.1 m height to 7.51 when 0.4 m. It does not affect results as much as area ratio. Although the tests show the effects of geometrical parameters, the results display an overestimated tendency due to the assumed small domain region. Therefore, large domain around the system is used for other tests.

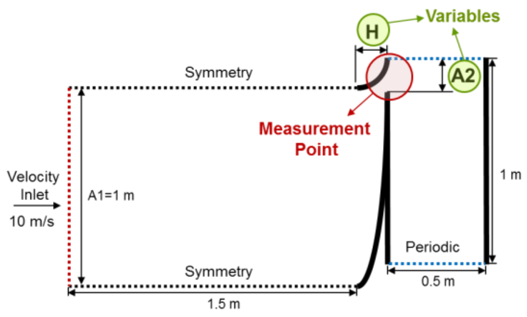


Fig. 3 solution domain

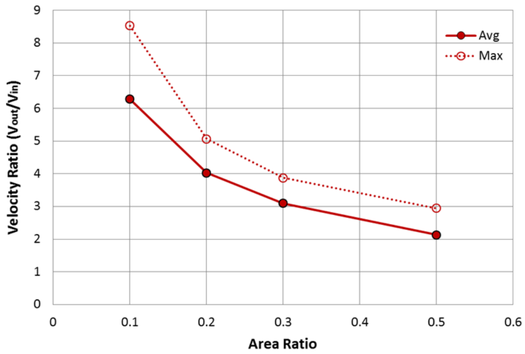


Fig. 4 Effect of area ratio

System back space The solution domain as shown in Fig. 5 is assumed in tests for the effect of system back space width. Assuming the same shape and dimension of module, several tests with different back space width from 5 cm to 50 cm are conducted. As a result, the output velocity ratio decreases rapidly when the width is less than 20cm width and the most efficient result appears when 30cm width.

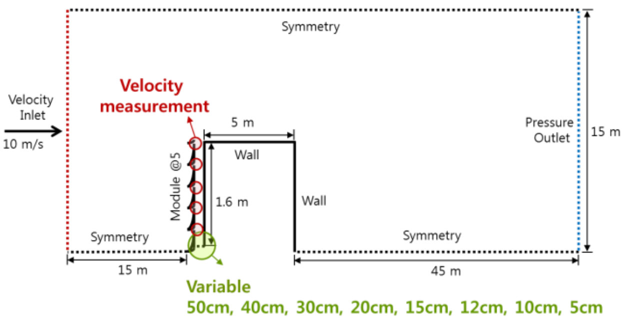


Fig. 5 solution domain

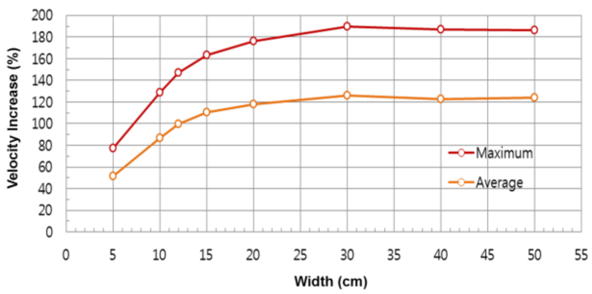
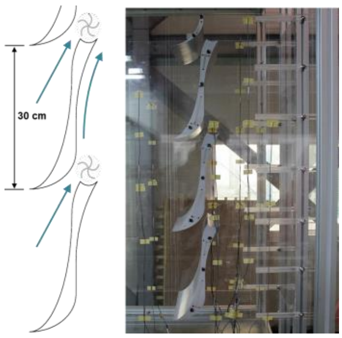


Fig. 6 Effect of back space width

3.2 Wind Tunnel Tests

For the experiments, guide vane prototypes of 30 cm length are manufactured and set up in wind tunnel as shown in Fig. 7. Wind velocity is measured at 8 points on both sides, totally 16 points. To check the reliability of simulations in 3.1, CFD analysis using same model and conditions with the experiment are performed. The results from wind tunnel experiment and CFD simulation are shown in Fig. 8. The points with number 9, 10, 13, and 14 represent output region. As a result, output velocity increase more than 200 % from reference input value. In addition, the results from wind tunnel test and CFD analysis are similar to certify simulation's accuracy.



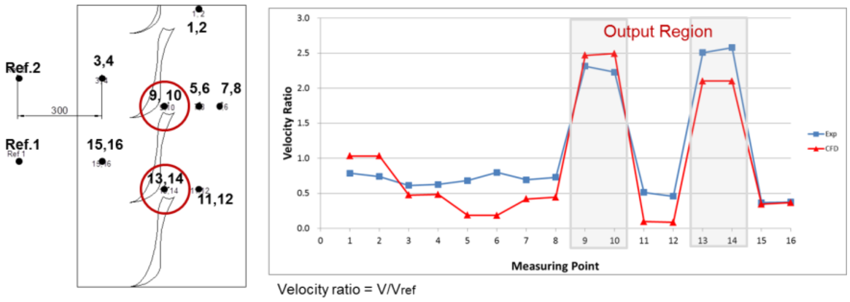


Fig. 7 Wind tunnel test Fig. 8 Results from experiment and simulation

4. CONCLUSIONS

In this study, an innovative building integrated wind turbine module which exploits wind pressure on building skin is proposed. To investigate geometrical effects of the guide vane parameters, the various CFD analyses are conducted. Through numerical simulations and experiments in wind tunnel, the velocity increase capability of the proposed guide vane is certified. In addition, the accuracy of results from numerical analysis is assured.

ACKNOWLEDGEMENT

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